Fifty-eighth Annual Convention
Hotel Windsor, Montreal, Canada
September 12-15, 1939

Volume 53 | March, 1939 | $4.00 a Year
Number 1 | Pages 1-120 | $1.25 a Number

JOURNAL

OF THE

New England Water Works Association

ISSUED QUARTERLY

Published by
THE NEW ENGLAND WATER WORKS ASSOCIATION
613 Statler Building, Boston, Mass.

Entered as second-class matter September 23, 1903, at the Post Office at Boston, Mass., under Act of Congress of March 3, 1879
Copyright, 1938, by the New England Water Works Association

OFFICERS
OF THE
New England Water Works Association
1938-1939

PRESIDENT

GEORGE A. SAMPSON of Weston & Sampson, Consulting Engineers, Boston, Mass.
(Term expires September, 1939)

VICE-PRESIDENTS

PERCY A. SHAW, Superintendent and Engineer, Water Works, Manchester, N. H.
(Term expires September, 1939)

LELAND G. CARLTON, Water Registrar, Springfield, Mass.
(Term expires September, 1940)

DIRECTORS

FRANCIS H. KINGSBURY, Massachusetts State Department of Health, Boston, Mass.
(Term expires September, 1939)

HAROLD L. BRIGHAM, Superintendent, Marlborough Water and Sewage Commission, Marlborough, Mass.
(Term expires September, 1940)

HORACE L. CLARK, Superintendent, Sanford Water District, Sanford, Me.
(Term expires September, 1941)

PAST PRESIDENTS
(Members of Executive Committee)

HARRY U. FULLER, Engineer, Portland Water District, Portland, Me.

WARREN J. SCOTT, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health, Hartford, Conn.

SECRETARY

FRANK J. GIFFORD, Dedham, Mass.

TREASURER

ABEL REYNOLDS, Treasurer, New England Water, Light & Power Associates, Providence, R. I.

EDITOR

GORDON M. FAIR, 112 Pierce Hall, Harvard University, Cambridge, Mass.

THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

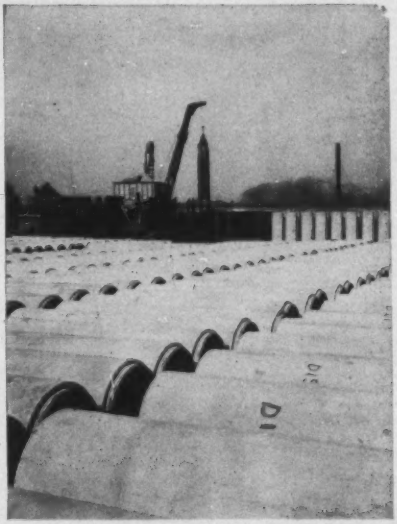
A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees	*Annual Dues*
Members	$ 3.00	$ 6.00
Juniors	1.00	3.00
Associates	10.00	20.00
Corporate Members	10.00	10.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.

The LOCK JOINT "Book of Experience"



800 Feet of Pipe per Day

Manufacturing Pipe at Little Rock, Ark.

MANUFACTURING and installing 800 feet of 39" diameter Concrete Pipe per day for Little Rock, Arkansas, to complete the job three months ahead of schedule was made possible by more than three decades of experience in Concrete Pipe construction.

When time is a factor in completing the job, you can always be assured of speed *plus* uniform high quality if Lock Joint Reinforced Concrete Pressure Pipe is used.

We will gladly furnish estimates on your proposed pipe lines. Write us for further details and specifications.

LOCK JOINT PIPE CO., Ampere, New Jersey
PRESSURE : SUBAQUEOUS : SEWER : CULVERT

LOCK JOINT Reinforced CONCRETE PRESSURE PIPE

HERE'S PITTSBURGH IMO ACCURACY

Not this

The following standard specifications cover the accuracy requirements of the American and New England Water Works Associations for ¾" cold water meters. Any conventional disc meter will meet them.

Allowable range (spread), 1 to 20 g.p.m., 4%

Minimum Test Flow, ¼ g.p.m., 90%

Or this

SPECIFICATIONS FOR BETTER QUALITY DISC METERS:

Allowable range (spread), 1 to 20 g.p.m., 2.2%

Low Flow Test, ¼ g.p.m., 95%

Minimum Test Flow, ⅛ g.p.m., 90%

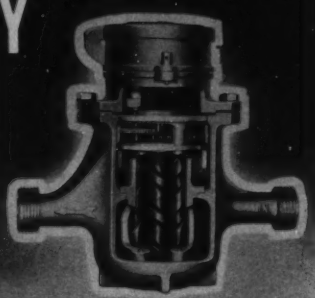
But this

STANDARD SPECIFICATIONS FOR PITTSBURGH IMO METERS:

Allowable range (spread), 1 to 20 g.p.m., 1.2%

Low Flow Test, ¼ g.p.m., 98%

Minimum Test Flow, 1/12 g.p.m., 90%



Water works men are becoming more and more "low flow conscious." They realize that thousands of dollars in revenue are being lost annually due to the inability of present meters to record, with any degree of accuracy, flows of water less than 1 g.p.m.

The Pittsburgh IMO Meter is the solution to the low flow measurement problem. Accuracy of 98% is guaranteed at ¼ g.p.m.—90% at 1/12 g.p.m. Actually, the majority of Pittsburgh IMO Meters will test better than this and it is commonplace to have these meters register 93% at 1/24 g.p.m. and even over 80% at 1/40 g.p.m.

It will pay you to get the complete story of the Pittsburgh IMO Meter. Write for Bulletin W-525.

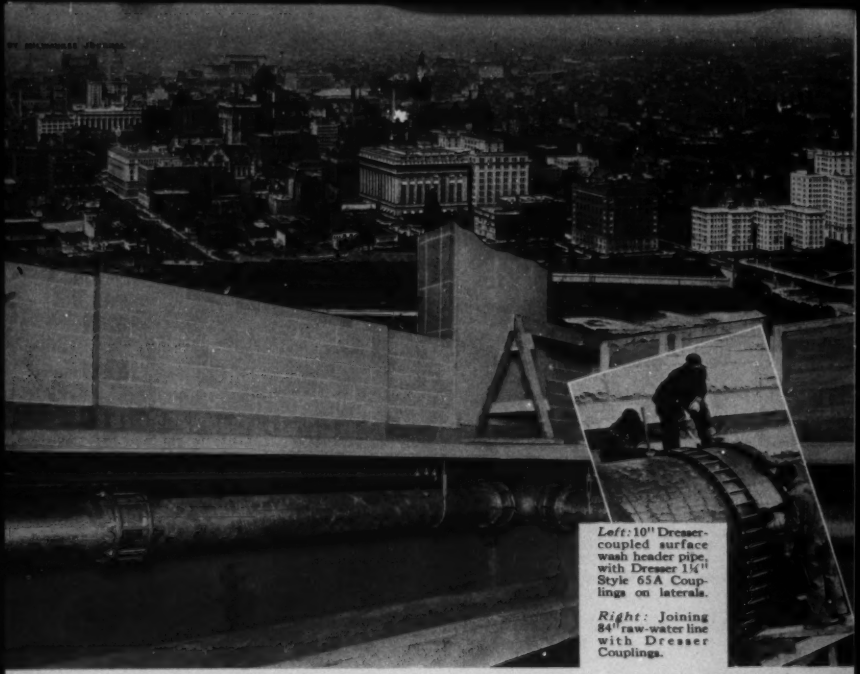
PITTSBURGH EQUITABLE METER COMPANY

MERCO NORDSTROM VALVE CO.

NEW YORK · BUFFALO · PHILADELPHIA · KANSAS CITY · TULSA · LOS ANGELES

Main Offices - PITTSBURGH, PA.

DES MOINES · CHICAGO · COLUMBIA · MEMPHIS · OAKLAND · HOUSTON



Left: 10" Dresser-coupled surface wash header pipe, with Dresser 1¼" Style 65A Couplings on laterals.

Right: Joining 84" raw-water line with Dresser Couplings.

Approved by MILWAUKEE!

ANOTHER city that marks the trend to Dresser Couplings is Milwaukee, Wis. Sizes including 1¼", 10", 36", 48", 60", and 84" are now in use at their new purification plant—on the raw-water line from pumps to basins, on wash-water lines to the filters, and on piping in the filters!

A METROPOLITAN TREND!

Many large and important cities are Dresser-coupling users. To mention a few:

Buffalo, N.Y. — Philadelphia, Pa.
Cleveland, Ohio — San Francisco, Cal.
Detroit, Mich. — St. Louis, Mo.

FIVE REASONS WHY MODERN WATER LINES ARE DRESSER-COUPLED:

1. PERMANENT TIGHTNESS—proved for 50 years, on 150,000 miles of pipe.
2. FLEXIBILITY—normal pipe movements—present in every line—are absorbed.
3. SIMPLICITY—joints are "factory-made"; ordinary labor can install.
4. STRENGTH—predetermined; joints safely withstand any specified pressure.
5. TRUE ECONOMY—a truly lower joint cost throughout the life of the line.

Write for our General Catalog No. 36.

Cutaway view of Dresser Coupling, Style 38, showing working principle. Note that plain-end pipe is used. The *resilient* rubber-compound gaskets, flexing with the pipe, easily absorb pipe movements, thus preventing failures that often occur with rigid joints.

THE MODERN TREND IS TO DRESSER COUPLINGS

S. R. DRESSER MFG. COMPANY, BRADFORD, PA. • 230 Park Avenue, New York, N.Y. • Peoples Gas Building, Chicago, Ill. • Shell Building, Houston, Tex.
1035 Folk Street, San Francisco, Calif. • *In Canada:* Dresser Mfg. Company, Ltd., 80 Front Street, West, Toronto, Ontario

Table of Contents

PAGE

Portrait of President George A. Sampson ..... *Frontispiece*

Public Surface Water Supplies in Massachusetts.
By Francis H. Kingsbury 1

Alignment Charts for the Design of Pipe Lines. By William F. Covil 103

Proceedings

November 1938 Meeting 116

December 1938 Meeting 116

January 1939 Meeting 118

February 1939 Meeting 118

Photo by Bachrach

GEORGE A. SAMPSON

President of the New England Water Works Association
1938-1939

New England Water Works Association
ORGANIZED 1882

Vol. LIII March, 1939 No. 1

This Association, as a body, is not responsible for the statements or opinions of any of its members

PUBLIC SURFACE WATER SUPPLIES IN MASSACHUSETTS

BY FRANCIS H. KINGSBURY*

[Read September 13, 1938.]

As stated in a paper on "Public Ground Water Supplies in Massachusetts" presented by the author before this Association on September 19, 1935,[1] water supplies are commonly classified as surface water supplies and ground water supplies. Because of the lively interest in methods of obtaining water from the ground evidenced at that time, ground water was made the subject of a symposium. The present paper has been prepared as a companion to the earlier one by the writer and together they should present a comprehensive view of the development of public water supplies in Massachusetts.

Surface water, as the name implies, runs off the surface of the ground to be collected in streams, ponds, lakes or reservoirs. Streams and impounding reservoirs, however, may often contain a mixture of surface water with ground water entering from springs or through rock crevices, the proportions varying with the precipitation, season of the year and other factors such as the character of the soil.

The population of Massachusetts according to the 1935 census was 4,350,910, of which 4,232,214 people, or 97.3 per cent, resided in communities served by public water supplies. While certain of the municipalities in the vicinity of Boston depended in earlier years upon ground water supplies and many of the larger cities at one time or another made use of such sources, the Boston Metropolitan Water District, since its formation under the provisions of Chapter 475 of the Acts of 1895, and many municipalities outside of the District are served wholly from surface sources. Attleboro, Lowell, Newburyport, Newton, Waltham and Woburn are the only cities supplied from ground water sources. The population of the municipalities supplied wholly from surface water sources is 3,245,617, as indicated by the 1935 census, that supplied wholly by ground water 754,409, and that supplied in part by surface and in part by ground water 232,188. A ready reference table (Table 1) is included here showing the individual municipalities, the kind of supply and the population served.

*Massachusetts Department of Public Health, Boston, Mass.
[1]This Journal 50 (1936), 149.

TABLE 1—MUNICIPALITIES IN MASSACHUSETTS PROVIDED WITH PUBLIC WATER SUPPLIES.

POPULATION—1935 CENSUS

SERVED FROM SURFACE WATER SOURCES

Abington	5,696	Ipswich	6,217
Acushnet	3,951	Lancaster	2,590
Agawam	7,206	Lawrence	86,785
Amherst	6,473	Lee	4,178
Andover	10,542	Lenox	2,706
Arlington	38,539	Leominster	21,894
Ashburnham	2,051	Lexington	10,813
Ashfield	918	Lincoln	1,573
Athol	10,751	Longmeadow	5,105
Barre	3,509	Ludlow	8,569
Belmont	24,831	Lynn	100,909
Beverly	25,871	Malden	57,277
Blackstone	4,588	Marlborough	15,781
Blandford	469	Maynard	7,107
Boston	817,713	Medford	61,444
Braintree	17,122	Melrose	24,256
Brockton	62,407	Middleton	1,975
Buckland	1,540	Milton	18,147
Cambridge	118,075	Monroe	240
Chelsea	42,673	Monterey	325
Cheshire	1,660	Nahant	1,748
Chester	1,362	New Bedford	110,022
Chicopee	41,952	North Adams	22,085
Clinton	12,373	Northampton	24,525
Concord	7,723	North Andover	7,164
Dalton	4,282	Northborough	2,396
Danvers	13,884	North Brookfield	3,186
East Bridgewater	3,670	Northfield	1,950
East Longmeadow	3,375	Peabody	22,082
Egremont	569	Pembroke	1,621
Everett	47,228	Pittsfield	47,516
Fall River	117,414	Plymouth	13,183
Falmouth	6,537	Quincy	76,909
Fitchburg	41,700	Randolph	7,580
Gardner	20,397	Revere	35,319
Gloucester	24,164	Rockland	7,890
Groveland	2,219	Rutland	2,406
Hadley	2,711	Salem	43,472
Hatfield	2,433	Saugus	15,076
Haverhill	49,516	Shelburne	1,606
Hinsdale	1,144	Somerville	100,773
Holbrook	3,364	Southborough	2,109
Holden	3,914	Southbridge	15,786
Holyoke	56,139	Southampton	954
Hudson	8,495	Southwick	1,540

TABLE 1 (*Continued*)

Spencer	6,487	Westhampton	405
Springfield	149,642	West Newbury	1,475
Stoneham	10,841	*West Springfield	17,118
Stoughton	8,478	Weymouth	21,748
Sunderland	1,182	Whitman	7,591
Swampscott	10,480	Wilbraham	2,969
Taunton	37,431	Williamsburg	1,859
Watertown	35,827	Winchester	13,371
West Bridgewater	3,356	Winthrop	17,001
West Boylston	2,158	Worcester	190,471
Westfield	15,788	Total	3,245,617

SERVED FROM GROUND WATER SOURCES

Acton	2,635	Gill	995
Amesbury	10,514	Grafton	7,681
Ashland	2,497	Granville	704
Attleboro	21,835	Groton	2,534
Avon	2,362	Hanover	2,709
Ayer	3,861	Hardwick	2,379
Barnstable	8,037	Harwich	2,373
Bedford	3,185	Holliston	2,925
Belchertown	3,863	Hopkinton	2,616
Bernardston	975	Kingston	2,743
Billerica	6,650	Littleton	1,530
Bourne	3,336	Lowell	100,114
Bridgewater	9,201	Mansfield	6,543
Brookline	50,319	Marblehead	10,173
Canton	6,505	Marion	1,867
Chatham	2,050	Marshfield	2,073
Chelmsford	7,595	Mattapoisett	1,682
Cohasset	3,418	Medfield	4,162
Cummington	610	Medway	3,268
Dedham	15,371	Merrimac	2,209
Douglas	2,403	Methuen	21,073
Dracut	6,500	Middleborough	8,865
Dudley	4,568	Millis	2,098
Dunstable	419	Nantucket	3,495
Duxbury	2,244	Natick	14,394
East Brookfield	945	Needham	11,828
Easthampton	10,486	Newton	66,144
Easton	5,294	North Attleborough	10,202
Edgartown	1,399	Northbridge	10,577
Fairhaven	11,005	North Reading	2,321
Foxborough	5,834	Norton	2,925
Franklin	7,494	Oak Bluffs	1,657
Georgetown	2,009	Oxford	4,249

*Auxiliary ground water supply under construction.

TABLE 1 (*Continued*)

Paxton	731	Waltham	40,557
Pepperell	3,004	Ware	7,727
Plainville	1,606	Warren	3,662
Provincetown	4,071	Wayland	3,346
Reading	10,703	Webster	13,837
Salisbury	2,245	Wellesley	13,376
Sharon	3,683	Westborough	6,073
Sheffield	1,810	West Brookfield	1,258
Shirley	2,548	Westford	3,789
Shrewsbury	7,144	Westminster	1,965
Somerset	5,656	Weston	3,848
Sterling	1,556	Westwood	2,537
Sturbridge	1,918	Wilmington	4,493
Sudbury	1,638	Winchendon	6,603
Sutton	2,408	Woburn	19,695
Tisbury	1,822	Worthington	530
Townsend	1,942	Wrentham	4,160
Uxbridge	6,397	Yarmouth	2,095
Walpole	7,449	Total	754,409

SERVED IN PART FROM SURFACE AND IN PART FROM GROUND WATER SUPPLIES

Adams	12,858	Milford	15,008
Auburn	6,535	Millbury	6,879
Brookfield	1,309	Monson	5,193
Colrain	1,554	Montague	7,967
Dartmouth	9,424	Newburyport	14,815
Deerfield	2,963	Norwood	15,574
Erving	1,283	Orange	5,383
Framingham	22,651	Palmer	9,437
Great Barrington	6,369	Rockport	3,634
Greenfield	15,903	Russell	1,283
Hanson	2,417	Scituate	3,846
Hingham	7,330	South Hadley	6,838
Hopedale	3,068	Stockbridge	1,921
Hull	2,619	Wakefield	16,494
Huntington	1,345	Wareham	6,047
Leicester	4,426	West Stockbridge	1,138
Lynnfield	1,896	Williamstown	4,272
Manchester	2,509	Total	232,188

Records of Surface Water Supplies. A search of the records of the development of surface water supplies in Massachusetts has revealed a mass of data which has been tabulated for convenience by decades to permit the recognition and comprehension of general facts as to the number and size of the several works made necessary by

the demands of an increasing population. Any consideration of surface water supplies must of course deal to a large extent with the sources of the Boston Metropolitan Water District and, accordingly, the tabulation includes an arrangement of its present sources of supply as well as the supplies in use by the several members of the District before its formation or before late members may have joined. In obtaining surface water supplies it has often been necessary for the larger communities to go some distance away. Considerations of economy and available resources have led to the joint development of other supplies in much the same manner as for the Metropolitan Water District, and certain municipalities with foresight have been prepared to meet the needs of ready customers once the works had been completed. A list of such agencies for joint supply, all from surface sources, follows:

Metropolitan Water District of Boston including:
Arlington, Belmont, Boston, Chelsea, Everett, Lexington, Malden, Medford, Melrose, Milton, Nahant, Quincy, Revere, Somerville, Stoneham, Swampscott, Watertown, Winthrop, and also Newton and Brookline which obtain only a portion of their supply from the district works. Clinton, Framingham, Southborough and Worcester have arrangements for taking water from the District sources.
Abington and Rockland (Joint Works)
Braintree, Randolph and Holbrook (Joint rights to supply)
Brockton:
Brockton, East Bridgewater, Easton (South Easton and Eastondale Fire and Water District), Hanson, Pembroke, West Bridgewater Fire and Water District, Whitman.
Clinton:
Clinton and Lancaster
Concord and Lincoln (Joint rights to supply)
Danvers:
Danvers and Middleton
Haverhill:
Haverhill, Groveland, West Newbury
Hingham (Hingham Water Company):
Hingham and Hull
Holden and Rutland (Joint rights to supply)
Holyoke:
Holyoke, Southampton
Lynn:
Lynn, Lynnfield Water District, Saugus, Peabody (Joint use of pipe line and pumping station on Ipswich River)
Milford (Milford Water Co.):
Milford, Hopedale
Montague (Turners Falls Fire District):
Turners Falls Fire District

TABLE 2A—MASSACHUSETTS SURFACE

Supplies of the Members of the

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Metropolitan Water Supply				
Boston (part of)				
Jamaica Pond Aqueduct Company	1796 Jamaica Pond A=0.1 D.A.=0.73	....	....	1892 Purchased by city abandoned
Boston (except Hyde Park Charlestown and East Boston)	1848-1859 Lake Cochituate A=1.25 D.A.=18.87 M.G.=2097	....	....	....
	1861 Dudley Pond D.A.=1			
	....	1875 Farm Pond A=0.26 D.A.=0.54 M.G.=168	....	Abandoned
	....	Sudbury River	Used Cochituate Aqueduct	....
	....	1878 Sudbury Res. No. 1 A=0.23 D.A.=1.84 M.G.=290	Used Sudbury Aqueduct	Not used
	....	1879 Sudbury Res. No. 2 A=0.21 D.A.=28.50 M.G.=530	....	....
	....	....	1885 (Ashland) Sudbury Res. No. 4 A=0.27 D.A.=6.43 M.G.=1416	....
	....	....	....	1894 Sudbury Res. No. 6 (Hopkinton) D.A.=5.86 M.G.=1521
	....	....	....	Whitehall Pond A=0.94 D.A.=4.35 M.G.=1257
	....	1878 Sudbury Res. No. 3 A=0.39 D.A.=5.40 M.G.=1200	....	....
	....	....	....	1895-98 Sudbury Res. No. 5 A=2.21 D.A.=22.28 M.G.=7254
Hyde Park	....	....	1885 Ground water supply	....

NOTE: A=Area of Reservoir in Square Miles.
D.A.=Drainage Area in Square Miles.
M.G.=Available Storage Capacity in Million Gallons.

WATER SUPPLIES AND DATES OF INSTALLATION

Metropolitan Water District and Worcester

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	....	....
1909 Dug Pond diverted 1910 Snake Brook diverted	1916 Dudley Pond abandoned	....	1931 Other small diversions	Lake Cochituate D.A.=17.4 M.G.=2097 Held in reserve
Metropolitan	....	....	....	....
....	....	....	....	....
....	....	....	....	....
Metropolitan Southern Sudbury System	....	....	....	Sudbury Res. No. 2 (In reserve)
....	....	....	....	Ashland Reservoir (Auxiliary)
....	....	....	....	Hopkinton Reservoir (Auxiliary)
....	....	....	....	Whitehall Pond (Auxiliary)
Metropolitan Northern Sudbury System	....	....	....	Sudbury Res. No. 3 (In regular use)
....	....	....	....	Sudbury Res. No. 5 (In regular use)
....	1911 Metropolitan Supply	....	....	....

TABLE 2A—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Charlestown	1864 Upper Mystic Lake A = 0.3 D.A. = 27.75 M.G. = 380	1878 Sewer constructed	....	1894 Salt water intrusion 1898 Metropolitan Mystic Works (abandoned)
East Boston	M.G. = 380	1875 Mystic Works	....	....
Chelsea	1867 Mystic Works Boston	....	....	....
Everett	1867 Mystic Works Boston	....	....	....
Somerville	1867 Mystic Works Boston	....	....	....
Arlington 1872 Town 1899 Metropolitan	....	1872 North Brook Reservoir A = 0.05 D.A. = 4.22 M.G. = 77 1876 Ground water, reservoir auxiliary	....	1899 Metropolitan Supply
Watertown 1885 Watertown Water Supply Co. 1897 Town 1898 Metropolitan	....	....	1885 Ground water	1898 Metropolitan Supply
Belmont 1887 Watertown Water Supply Co. 1898 Metropolitan	....	....	1887 Ground water Watertown	1898 Metropolitan Supply
Lexington 1884 Lexington Water Co. 1895 Town 1903 Metropolitan	....	....	1884 Ground water	1897 Vine Brook Res. A = 0.01 D.A. = 0.30 M.G. = 14
Malden 1870 City 1898 Metropolitan	Each had one-third rights in Spot Pond	1870 Spot Pond A = 0.41 D.A. = 2.03 M.G. = 837 at 15 ft.	1889 Ground water Additional supply	1898 Metropolitan Supply
Melrose 1870 City 1898 Metropolitan		1870 Spot Pond	....	1893 Ground water Additional supply 1898 Metropolitan Supply
Medford 1870 City 1898 Metropolitan		1870 Spot Pond	1883 Small receiving reservoir for pumping	1898 Metropolitan Supply
Milton 1890 Hyde Park Water Co. to Milton Water Co. 1902 Town 1903 Metropolitan	....	....	1890 Hyde Park Water Company Ground water	....
Nahant 1885 Marblehead Water Co. 1898 Metropolitan	....	....	1885 Marblehead Water Co. Ground water	1899 Metropolitan Supply

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....		....	....
....	....	....	....	....
....	....	....	....	....
1903 Metropolitan Supply	....	....	....	....
Spot Pond taken by Metropolitan for a distribution reservoir	....	....	....	Spot Pond distributing reservoir for Metropolitan
	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

TABLE 2A—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Quincy 1884 City 1897 Metropolitan		....	1884 Ground water 1888 Town Brook Res. A = 0.07 D.A. = 1.55 M.G. = 180	1897 Metropolitan Supply
Revere	....	....	1884 Ground water	1898 Metropolitan Supply
Revere Water Co. City	....	....	1889 Crystal Brook	....
Winthrop (Revere Water Co.) Town	....	....	1884-1889 Revere Water Co.	1898 Metropolitan Supply
Stoneham	....	....	1883 Crystal Lake Wakefield Water Co.	....
Swampscott	....	....	1885 Marblehead Water Co. Ground water	1899 Metropolitan Supply
Brookline	....	1875 Ground water supply	Charging ditch and and connection to river	....
Newton	....	1876 Ground water supply	....	1898 Metropolitan Supply available
Worcester	1854 Bell Pond M.G. = 330	....	....	....
	1864 Lynde Brook Reservoir D.A. = 2.92	1871 Dam raised A = 0.22 M.G. = 681	....	....
	....	....	1883 Tatnuck Res. A = 0.15 D.A. = 4.71	1892 Dam raised M.G. = 450
	....	....	....	....
	....	....	....	1896 Kettle Brook Res. No. 1 A = 0.01 D.A. = 4.10 (total) M.G. = 19
	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
1901 Metropolitan Supply	....	....	....	....
....	....	....	....	....
....	1911 Charging basins River water	1925 Metropolitan Supply	1937 Metropolitan Supply only M.G. = 71.9	Ground water supply and from Metropolitan
1909 Charging bowls River water	1928-1934 Charging bowls River water	....	1937 Metropolitan Supply only M.G. = 21.1 1937 New dug wells	Ground water supply and from Metropolitan
....	....	....	....	....
....	....	....	....	Lynde Brook Res. A = 0.21 D.A. = 2.92 M.G. = 701
....	Raised again	....	....	Upper Holden Res. A = 0.09 D.A. = 0.68 M.G. = 729
1901 Holden Reservoir No. 1 A = 0.21 D.A. = 5.23 M.G. = 257	....	....	....	Lower Holden Res. A = 0.21 D.A. = 5.23 M.G. = 257
....	....	....	....	Kettle Brook Res. No. 1 A = 0.01 D.A. = 1.00 M.G. = 19
1902 Kettle Brook Res. No. 2 A = 0.05 D.A. = 0.57 M.G. = 127	....	....	....	Kettle Brook Res. No. 2 A = 0.05 D.A. = 0.57 M.G. = 127

TABLE 2A—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Worcester (Continued)	....	....	....	....
	....	....	....	....
	....	....	....	....
	....	....	....	....
	....	....	....	....
	....	....	....	....
	....	....	....	....
	....	....	....	....
Auburn (Parts supplied from Worcester)				
Woodland Park Water Dis.	....	....	....	....
Elm Hill Water Dis.	....	....	....	....
Millbury				
Maple Hillside Water District	....	....	....	....
West Boylston (Part supplied from Worcester)				
Pinecroft Water District	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
1903 Kettle Brook Res. No. 3 A = 0.06 D.A. = 0.72 M.G. = 152				Kettle Brook Res. No. 3 A = 0.06 D.A. = 0.72 M.G. = 152
1902 Kettle Brook Res. No. 4 A = 0.19 D.A. = 1.81 M.G. = 514				Kettle Brook Res. No. 4 A = 0.19 D.A. = 1.81 M.G. = 514
	Part of Metropolitan Watershed			Total drainage area formerly held by the Metropoliton 22.75 sq. miles
	1906-1911 Asnebumskit Brook Canal to Holden Res.			
	1911-1914 Kendall Res. A = 0.27 D.A. = 2.45 M.G. = 792			Kendall Reservoir A = 0.27 D.A. = 2.45 M.G. = 792
	1911 Pipe line to Wachusett Reservoir	Since abandoned		
		1924 Pine Hill Res. A = 0.72 D.A. = 6.90 M.G. = 2971		Pine Hill Res A = 0.72 D.A. = 6.90 M.G. = 2971
			Quinepoxet Pond A = 0.26 D.A. = 13.40 M.G. = 230	Quinepoxet Pond A = 0.26 D.A. = 13.40 M.G. = 230 (Pumps not yet installed)
			1933 Woodland Park Water District	Worcester Supply
			1938 Elm Hill Water District	Plans for Worcester Supply
			1936 Maple Hillside Water District	Worcester Supply
			1933 Worcester Supply	Worcester Supply

TABLE 2B—MASSACHUSETTS SURFACE WATER

Present Sources of Supply of

System	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Cochituate System	1848-1859 Lake Cochituate A = 1.25 D.A. = 18.87 M.G. = 2097	Supplied through the Cochituate Aqueduct, various diversions from watershed		
Southern Sudbury System	....	1878 Sudbury Res. No. 1. A = 0.23 D.A. = 1.85 M.G. = 290 1879 Sudbury Res. No. 2 A = 0.21 D.A. = 28.50 M.G. = 530	....	....
	....	....	1885 Sudbury Res. No. 4 (Ashland Res.) A = 0.27 D.A. = 6.43 M.G. = 1416	....
	....	....	....	1894 Sudbury Res. No. 6 (Hopkinton Res.) A = 0.30 D.A. = 5.86 M.G. = 1521
	....	....	....	1890-1896 Whitehall Pond A = 0.94 D.A. = 4.35 M.G. = 1257
Northern Sudbury System	....	1878 Sudbury Res. No. 3 A = 0.39 D.A. = 5.40 M.G. = 1200	....	....
	....	....	....	1895-1898 Sudbury Res. No. 5 A = 2.21 D.A. = 22.28 M.G. = 7254
South Branch of the Nashua River	....	....	....	....
Ware River at Coldbrook	....	....	....	....
Swift River at West Ware	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION
the Metropolitan Water District

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
				Abandonment proposed after initial distribution tunnel is completed D.A. = 17.4 M.G. = 2097
....	Reservoir No. 1 and No. 2 Practically abandoned, held in reserve	....	....	
		1927 Emergency pumping station at Cordaville for pumping to Sudbury Res. No. 5		
....	....	1927 Pipe line to Sudbury Res. No. 5 for water from Ashland Reservoir, Hopkinton Reservoir and Whitehall Pond	....	Sudbury System. Proposed to be held as an emergency reserve supply upon completion of proposed distribution tunnel from Wachusett Aqueduct to the Metropolitan Area D.A. = 74.64 M.G. = 10,000
....	....	....	....	
....	....	....	....	
....	....	....	....	
1908 Wachusett Res. A = 6.46 D.A = 118.19 M.G. = 65,000	1914 (See Worcester) D.A. = 108.84	....	1926-1931 (See Worcester) D.A. = 88.04 M.G. = 45,000 1937 Diversion of East Waushakum Pond D.A. = 1.15	
....	....	....	1931 Ware River Tunnel completed and first used D.A. = 96.8	Nashua, Ware and Swift rivers. Proposed as the future supply for the Metropolitan Water District to be supplied directly from Wachusett Aqueduct or Wachusett Reservoir in tunnels to the Metropolitan Area D.A. = 269.7 M.G. = 440,000
....	....	....	1935 Swift River Tunnel completed. (Not yet used) 1938 Quabbin Reservoir well under way, filling expected to start 1939 A = 38.6 D.A. = 185.9 M.G. = 395,000	

TABLE 2C—MASSACHUSETTS SURFACE

Municipalities Other Than Worcester

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Abington & Rockland	....	....	1887 Big Sandy Bottom Pond A=0.18 D.A.=0.60 M.G.=563 Filter gallery unsuccessful	....
Acushnet Acushnet Fire and Water District	....	....	....	....
Adams 1873 South Adams Fire District 1881 Adams Fire District	....	1873 Bassett Brook Reservoir D.A.=2.6 M.G.=2.8	1886 Well (Renfrew) 1883 Dry Brook Reservoir D.A.=7.8 M.G.=1.8	1895 Wells (Zylonite)
Agawam 1877 C. L. Goodhue 1905 Town	....	1877 Ground water supply	....	....
Amherst 1887 Spring Water Co. 1880 Amherst Water Co.	....	1880 Amethyst Brook Intake Res. D.A.=6.30	....	....
Andover	....	....	1890 Haggett's Pond A=0.31 D.A.=2.70 M.G.=1038	....
Ashburnham	1870 Small Reservoir 30 Families	....	....	....
Ashfield Ashfield Water Co.	1875—Many years prior to	....	....	....
Athol 1875 Athol Aqueduct Co. 1904 Town	....	1875 Phillipston Reservoir A=0.03 D.A.=0.66 M.G.=50	1884 Silver Lake 1887 Buckman Brook D.A.=0.89	Silver Lake abandoned
Attleboro 1873 Attleboro Water Supply District 1893 Town 1914 City	....	1873 Ground water supply	1882 Ground water supply	1892 Ground water supply
Barre 1895 Barre Water Co. 1905 Town	....	....	....	1895 Reservoir on Allen's Hill A=0.01 D.A.=None M.G.=12

WATER SUPPIES AND DATES OF INSTALLATION
and Those of the Metropolitan Water District

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	....	Big Sandy Bottom Pond A = 0.18 D.A. = 0.60 M.G. = 563
....	1916 New Bedford Supply	....	....	....
1902 Tubular Wells	....	Dry Brook Reservoir abandoned	1934 New Bassett Brook Res. D.A. = 2.8 M.G. = 0.75	Bassett Brook Res. Ground water supply New Bassett Brook Res.
1905 West Springfield Supply	1912 and 1915 Springfield Supply	....	....	Springfield Supply
1909 Hills Reservoir D.A. = 4.3 M.G. = 26	....	....	1931 Atkins Pond (Emergency) Nourse Brook	Amethyst Brook Intake Res. Hawley Res. Hills Res. Atkins Pond (Emerg.)
....	....	....	....	Haggett's Pond A = 0.31 D.A. = 2.70 M.G. = 1038
....	1912 Upper Naukeag Lake A = 0.41 D.A. = 2.07 M.G. = 400	....	....	Upper Naukeag Lake A = 0.41 D.A. = 2.07 M.G. = 400
1904 Bear Swamp Res. D.A. = 0.45 M.G. = 4.0 Highland Spring Res. M.G. = 0.2	....	....	....	Bear Swamp Res. D.A. = 0.45 M.G. = 4.0 Highland Spring Res. M.G. = 0.2
1904-1909 Newton Res. D.A. = 0.89 M.G. = 83	1912 Thousand Acre Meadow Brook Res. D.A. = 3.25 M.G. = 1.5 1918 Lake Ellis (Emergency)	1924 Newton Dam raised A = 0.02 D.A. = 0.89 M.G. = 87	....	Phillipston Res. Newton Res. Thousand Acre Meadow Brook Res. Lake Ellis (Emergency)
1904-1907 Ground water supply 1907 Orr's Pond A = 0.06 D.A. = 2.30 M.G. = 40	1911 Hoppin Hill Res. A = 0.06 D.A. = 2.15 M.G. = 145	1929 Ground water supply	1935-1936 Ground water supply	Ground water supply and charging filter Orr's Pond (Emergency) Hoppin Hill Res. Charging water for well supply
....	....	....	....	Reservoir on Allen's Hill A = 0.01 D.A. = None M.G. = 12.0

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Barre (Continued)				Brook diverted Intake D.A. = 0.43 M.G. = 0.3 Allen's Pond (Emergency) A = 0.27 D.A. = 4.6 M.G. = 186±
Bellingham	....	....	....	....
Beverly (See Salem)	....	....	....	....
Blackstone	....	....	....	....
Blandford Blandford Fire District	....	....	....	....
Braintree 1887 Braintree Water Supply Co. 1891 Town	....	....	1887 Filter gallery at Little Pond	1893 Connection to Little Pond 1897 Tubular wells abandoned
Brockton	....	1880 Avon Res. A = 0.15 D.A. = 3.11 M.G. = 309 1½ acres underdrained to obtain filtered water (Never used)	1887 Isolation of meadow by dikes	....
East Bridgewater 1888 Bridgewater Water Co. 1908 Town	....	....	1888 Ground water	....
Easton South Easton and Eastondale Fire and Water District	....	....	....	....
Hanson	....	....	....	....
Pembroke	....	....	....	....
Whitman	....	....	1883 Ground water connection to Pond	....
Brookfield	....	....	1889 Cooley Hill Res. D.A. = 0.12 M.G. = 2.6 (Originally for fire purposes)	....
Buckland Part included in Shelburne Falls Fire District	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
				Intake Res. (Small) D.A. = 0.43 M.G. = 0.3 Allen's Pond (Emergency) A = 0.27 D.A. = 4.6 M.G. = 186±
....	....	....	1934 Woonsocket, R. I. Supply	Woonsocket, R. I. Supply
....	....	....	....	(See Salem)
...	1911 Woonsocket, R. I. Supply	....	....	Woonsocket, R. I. Supply
1909 Freeland Brook Res. D.A. = 0.14 M.G. = .07		....	1930 Freeland Brook Intake D.A. = 0.56	Freeland Brook Res Freeland Brook Intake (Emer.)
1902 Great Pond (Emergency)	1912 All work at Little Pond abandoned for domestic use 1912 Great Pond A = 0.25 D.A. = 3.48 M.G. = 271	Little Pond for industrial use only	1935-1936 Great Pond Raised 1½ ft. A = 0.39 M.G. = 386	Great Pond A = 0.39 D.A. = 3.48 M.G. = 386 Used jointly with Randolph and Holbrook
1904 Silver Lake A = 1.01 D.A. = 4.39 M.G. = 5,371	....	....	....	Avon Res. (Emergency) A = 1.01 D.A. = 3.11 M.G. = 309 Silver Lake A = 1.01 D.A. = 4.39 M.G. = 5,371
1908 Brockton Supply	....	....	....	Brockton Supply
...	1915 Brockton Supply	....	....	Brockton Supply
....	1920 In part by Brockton	1930 In part by Rockland and Hanover	....	Brockton, Rockland and Hanover tubular wells
....	1913 Brockton Supply	....	....	Brockton Supply
1905 Brockton Supply	....	....	....	Brockton Supply
....	1912-1915 Ground water supply	1930 Ground water supply	....	Cooley Hill Res. D.A. = 0.12 M.G. = 2.6 Dug and tubular wells
....	1912 Shelburne Falls Fire District	....	....	Shelburne Falls Fire District

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Cambridge 1806 Cambridgeport Aqueduct Co. 1852 Cambridge Water Works (Private Company) 1865 City	1806 Ground water supply 1856 Fresh Pond A = 0.27 D.A. = 1.25 M.G. = 400	Filter gallery at Little Pond 1876 Wellington Brook	1887 Stony Brook Res. A = 0.11 D.A. = 25.16 M.G. = 402	1897 Hobbs Brook Res. A = 0.87 D.A. = 6.93 M.G. = 2990
Charlemont (Private)	....	....	1889 Mine Brook for fire purposes—not approved for domestic use.	....
Cheshire Cheshire Water Co.	....	1876 Thunder Brook Res. D.A. = 1.65 M.G. = .05	....	1896 Kitchen Brook Res. D.A. = 2.46 M.G. = .025
Chester 1893 Charles L. Goodhue 1893 Chester Fire District 1932 Town	....	....	....	1893 Austin Brook Res. D.A. = 1.25 M.G. = 0.2
Chicopee 1877 Chicopee Water Co.	....	1877 Abbe Brook Reservoir D.A. = 0.75 M.G. = 5.3 Sand Bank Pond D.A. = Small	....	....
Chicopee Mfg. Co. 1883 Chicopee Falls Fire District	....	....	1883 Chicopee River Canal	1892 Typhoid 1893 Canal abandoned
Chicopee Mfg. Co.	Springs prior to 1876	....	....	....
1892 Willimanset Water Co. (Purchased by city 1893)	....	....	....	Willimanset Res. and Sherman Res.
1892 City	....	....	....	1893 Cooley Brook Res. D.A. = 4.55 M.G. = 5.5 1893 Morton Brook Res. D.A. = .35 M.G. = 0.2
Clinton	....	....	1882 Spring Basin A = 0.01 1883 Upper Lynde's Brook Res. A = 0.01 1882 Lower Lynde's Brook Res. 1886 Fitch Pond A = 0.02 Total D.A. = 0.96 Total M.G. = 83	1899 Heywoods Pond A = 0.06 D.A. = 0.71

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
Fresh Pond area reduced by diking off shallow flowage	....	....	1932 Fresh Pond New intake A = 0.15 M.G. = 1200	Fresh Pond Stony Brook Res. Hobbs Brook Res.
....	....	....	....	Mine Brook (Not approved)
....			Thunder Brook (Emergency)	Kitchen Brook Res. D.A. = 2.46 M.G. = .025
....	1912 Horn Pond A = 0.05 D.A. = 0.45 M.G. = 40	....	....	Austin Brook Res. Horn Pond
....	....	Abandoned in 1927	....	....
....	....	....	....	....
....	....	....	....	....
1909 Ground water supply Emergency	....	Abandoned in 1927	....	....
....	....	1927 Cooley Brook Res. enlarged M.G. = 135	....	Cooley Brook Res. A = 0.5 D.A. = 4.55 M.G. = 135 Morton Brook Res. D.A. = 0.35 M.G. = 0.2
....	1913-14-15 Heywoods Pond cleaned, dam raised M.G. = 28	1926 Heywoods Pond Dam raised again M.G. = 171 1923 Wachusett Res. (Lancaster Mills)	....	Spring Basin, Upper and Lower Lynde's Res. and Fitch Pond Total A = 0.04 D.A. = 0.96 M.G. = 83 Heywoods Pond A = 0.06 D.A. = 0.71 M.G. = 171 Wachusett Reservoir Auxiliary Supply

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Lancaster	....	....	1885 Clinton Supply	....
Colrain Colrain Fire Dist. No. 1	....	....	....	....
Griswoldville Mfg. Co.	....	....	....	1900 Springs and river water Typhoid
Concord	....	1874 Sandy Pond A=0.25 D.A.=0.72 M.G.=300	....	....
Lincoln	....	1874 Sandy Pond (See Concord)	....	....
Dalton Dalton Fire District	....	....	1884 Egypt Brook Res. D.A.=1.00 M.G.=3.7	1894 New Reservoir - Egypt Brook A=0.01 D.A.=1.00 M.G.=7.8
Danvers 1796 Salem Aqueduct Co 1876 Town	1796-1839 Springs	1876 Middleton Pond A=0.14 D.A.=1.45 M.G.=500	1884 Middleton Dam at Outlet A=0.23 D.A.=1.45 M.G.=766	1893 Swan Pond A=0.07 D.A.=0.18 M.G.=185
Dartmouth	....	....	....	....
Deerfield So. Deerfield Water Supply District	....	....	....	....
East Bridgewater	....	....	....	....
Easthampton	1870 Reservoir M.G.=5.2	....	....	....
East Longmeadow	....	....	....	....
Easton North Easton Village District Unionville Fire and Water District Easton Centre Water District	....	....	1887 Reservoir with underdrains. Never used 1887 Ground water supply	....
South Easton and Eastondale Fire and Water District	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	....	Clinton Supply
1902 Mountain Brook Res. D.A. = 0.33 M.G. = 0.1 1909 Dam raised M.G. = 0.2	....	....	....	Mountain Brook Res. D.A. = 0.33 M.G. = 0.2
1901 McClellan Brook Res. 1907 Dam raised D.A. = 0.44 M.G. = 0.2	....	....	....	McClellan Brook Res. D.A. = 0.44 M.G. = 0.2
1909 Nagog Pond A = 0.45 D.A. = 1.22 M.G. = 879	....	....	....	Nagog Pond Sandy Pond
....	....	....	....	Sandy Pond Joint Rights with Concord
1904 Anthony Brook (Intake) D.A. = 0.50	1916 Beal's Brook (Intake) D.A. = 0.62	....	1936 Cady Brook discharge direct to Windsor Res.	Egypt Brook Res. Anthony Brook (Intake)
1910 Cady Brook (Intake) D.A. = 3.86	1916 May Brook (Intake) D.A. = 2.34 1919 Windsor Res. A = 0.12 D.A. = 15.20 M.G. = 222		1936 Beal's Brook abandoned	May Brook (Intake) Windsor Res.
....	....	....	....	Middleton Pond Swan Pond
....	1915 New Bedford Supply	....	....	New Bedford Supply for part of Town
1903 Roaring Brook Res. D.A. = 4.00 M.G. = 1.5	....	....	....	Roaring Brook Res. D.A. = 4.00 M.G. = 1.5
1908 Brockton Supply	....	....	....	Brockton Supply
1909 Ground water supply	....	....	....	Ground water supply
....	1913 Springfield Supply	....	....	Springfield Supply
....	....	....	....	Ground water supply
....	1915 Brockton Supply	....	....	Brockton Supply

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Egremont South Egremont Water Co.	....	....	....	....
Erving Millers Falls Fire and Water District	....	....	....	1896 See Montague
Fall River	....	1874 North Watuppa Pond A = 2.82 D.A. = 11.4 M.G. = 10,000	....	....
Falmouth 1893 Falmouth Heights Water Company 1899 Falmouth Water Company 1902 Town	....	....	....	1893 Ground water supply 1899 Ground water supply Never used to any great extent 1899 Long Pond A = 0. 34 D.A. = 1.12 M.G. = 710
Fitchburg	....	1872 Intake on Scott Brook 1875 and 1880 Scott Res. reconstructed A = 0.06 D.A. = 0.76 M.G. = 210	1883 Falulah Res. A = 0.01 D.A. = 3.76* M.G. = 14	1893 Meetinghouse Pond A = 0.24 D.A. = 1.47 M.G. = 1015
Framingham 1885 Framingham Water Co. 1905 Town	....	....	1885 Ground water supply 1885 Boston Water Supply Sudbury Aqueduct	....
Franklin 1884 Franklin Water Co. 1907 Town	....	....	1884 Ground water supply Connection to Pond used until 1887	....
Gardner 1882 Gardner Water Co. 1902 City	....	....	1882 Crystal Lake A = 0.24 D.A. = 0. 95 M.G. = 461	....
Gloucester 1885 Gloucester Water Supply Co. 1895 City	....	....	1885 Dike's Meadow Res. A = 0.09 D.A. = 0.68 M.G. = 210 1885 Wallace Brook Res. A = 0.04 D.A. = 0.29 M.G. = 54 Fernwood Lake A = 0.04 D.A. = 0.31 M.G. = 25	Fernwood Lake used as emergency supply

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	1913 Goodale Brook Res. D.A. = 2.50 M.G. = 0.05	....	....	Goodale Brook Res. D.A. = 2.50 M.G. = 0.05
....	....	....	....	See Montague Turners Falls Fire District
....	1916 Diversion Ditch D.A. = 9.12	1924 Long Pond (Lakeville Ponds) See Chap. 400 Acts 1924	1932 New diversion from North Watuppa Pond	North Watuppa Pond A = 2.82 D.A. = 8.65 M.G. = 10,000 Long Pond (Lakeville Ponds) Allocated but not in use
....	....	....	....	Long Pond A = 0.34 D.A. = 1.12 M.G. = 710
1907 Wachusett Lake A = 0.18 D.A. = 1.52 M.G. = 327	1915 Ashby Res. A = 0.24 D.A. = 2.16* M.G. = 700	1927 Lovell Res. A = 0.05 D.A. = 3.38* M.G. = 450	....	Scott Reservoir Falulah Res. Meetinghouse Pond Wachusett Lake Ashby Res. Lovell Res. *Ashby Res. and Lovell Res. are above Falulah Res. Total D.A. = 3.76
....	....	....	....	Ground water supply about one-third. Metropolitan Supply about two-thirds
....	....	....	....	Ground water supply
1909 Perley Brook (Intake) D.A. = 2.75	....	....	....	Crystal Lake Perley Brook (Intake Res.) pumped to Crystal Lake
1903 Haskell Brook Res. A = 0.10 D.A. = 0.64 M.G. = 427	....	1930 Babson Res. A = 0.06 D.A. = 1.75 M.G. = 175	Fernwood Lake abandoned 1931	Dike's Meadow Res. Wallace Brook Res. Haskell Brook Res. Babson Res.

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Great Barrington 1868 Great Barrington Water Company	1868 E. Mountain Reservoir D.A. = 0.28 M.G. = 3.0	....	....	1892 Purchased by District
1885 Mansfield Lake Water Co.	....	....	1885 Lake Mansfield A = 0.06 D.A. = 0.17 M.G. = 100	1894 Given to District
1886 Berkshire Heights Water Company	....	....	1886 Intake on Green River	1893 Purchased by District
1892 Great Barrington Fire District	....	....	....	1895 Green River New Intake
1888 Housatonic Water Works Company	....	....	1888 Long Pond A = 0.22 D.A. = 1.27 M.G. = 240	....
Greenfield 1870 Greenfield Fire District 1922 Town	1870 Lower Glenn Brook Res. A = 0.01 D.A. = 5.36 M.G. = 25	....	....	....
Groveland	....	....	....	....
Hadley Hadley Water Supply District	....	....	....	....
Hanson	....	....	....	....
Hatfield	....	....	....	1896 Running Gutter Brook Res. D.A. = 0.28 M.G. = 2.6
Haverhill 1802 Haverhill Aqueduct Co. 1891 City	1802 Lake Pentucket (Round Pond) A = 0.06 D.A. = 0.49 M.G. = 142 1867 Lake Saltonstall A = 0.07 D.A. = 0.32 M.G. = 66 1867 Kenoza Lake A = 0.35 D.A. = 1.60 M.G. = 725	....	1884 Crystal Lake A = 0.25 D.A. = 3.24 M.G. = 428	1895 Millvale Res A = 0.07 D.A. = 7.82 M.G. = 118

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
1905 Reservoir enlarged D.A. = 0.28 M.G. = 4.0	....	....	....	East Mountain Res. D.A. = 0.28 M.G. = 4.0
....	....	....	....	Lake Mansfield abandonment recommended
1905 Ground water supply	....	....	....	....
1905 Ground water supply	....	....	1934 New ground water supply	Ground water supply
....	....	....	....	Long Pond A = 0.22 D.A. = 1.27 M.G. = 240
1904 Upper Glenn Brook Res. A = 0.01 D.A. = 5.15 M.G. = 45	1913 Well and charging filter at Green River	....	....	Lower Glenn Brook Res. Upper Glenn Brook Res. Well and charging filter at Green River
....	1915 Haverhill Supply	....	....	Haverhill Supply
1905 Upper Harts Brook Res. D.A. = 0.2 M.G. = 9.0	....	1930 Lower Harts dam raised	....	Upper Harts Brook Res. D.A. = 0.2 M.G. = 9.0
1909 Lower Harts Brook Res. D.A. = 0.08 M.G. = 0.6				Lower Harts Brook Res. D.A. = 0.08 M.G. = 2.0
....	1920 Brockton Supply	1930 Rockland surface water supply Hanover ground water supply	....	Brockton, Rockland, Hanover Supplies
....	....	....	....	Running Gutter Brook Reservoir D.A. = 0.28 M.G. = 2.6
....	....	....	1932 Lake Saltonstall abandoned Used in emergency in 1929	Round Pond (Emergency) D.A. = 0.49 Kenoza Lake Crystal Lake Millvale Res.

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Haverhill (Continued) Bradford (Annexed to Haverhill in 1897)	....	....	Ground water supply	1891-1892 Ground water supply
1886 Bradford Water Co. 1895 Town	....	....	....	1896 Hovey's Pond A=0.05 D.A.=0.22* M.G.=30 1896 Chadwick Pond A=0.18 D.A.=1.60* M.G.=316 1896 Johnson's Pond A=0.35 D.A.=5.09* M.G.=1014 (Total D.A.=5.09*)
Groveland	....	....	....	....
West Newbury	....	....	....	....
Hingham and Hull Hingham Water Co. Supplied Hingham 1880 Supplied Hull 1882	....	1880 Accord Pond A=0.15 D.A.=0.72 M.G.=482	1886 Fulling Mill Pond A=0.02 D.A.=0.36 M.G.=34	Ground water basins
Hinsdale Hinsdale Fire District	....	....	1889 Belmont Res. Steam Sawmill Brook A=0.01 D.A.=0.34 M.G.=35	....
Holbrook	....	....	1888 Great Pond (See Randolph and Braintree)	....
Holden	....	....	....	....
Holyoke 1849 Hadley Company 1857 Holyoke Water Power Co. 1873 City	1849 Connecticut River Artificial Res. M.G.=3	1873 Abandoned Connecticut River. Wright and Ashley Ponds A=0.36 D.A.=2.58 M.G.=1509	....	....
Southampton (1931 Manhan River Supply)	1870 Crystal Springs	....	1881 Tannery Brook 1883 Bray Brook Res. A=0.03 D.A.=0.89 M.G.=20 1884 Lower Whiting Street Brook Res. D.A.=1.66* M.G.=1.0	1897-1898 Manhan River Supply Former Res. A=0.02 D.A.=13.0* M.G.=24 (Diverted to Ashley Pond 1899 High-service Res. D.A.=0.47 M.G.=354

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	....	....
....	....	....	....	Hovey's Pond A = 0.05 D.A. = 0.22* M.G. = 30 Chadwick Pond A = 0.18 D.A. = 1.60* M.G. = 316 Johnson's Pond A = 0.35 D.A. = 5.09* M.G. = 1014 (Total D.A. = 5.09*)
....	1915 Haverhill-Johnson's Pond Supply	....	....	Haverhill-Johnson's Pond Supply
....	....	....	1936 Haverhill-Groveland Johnson's Pond Supply	Haverhill-Groveland Johnson's Pond Supply
1903 Wells and collecting drains	....	....	....	Accord Pond Ground water supply
....	....	....	....	Belmont Res. Steam Sawmill Brook A = 0.01 D.A. = 0.34 M.G. = 35
....	....	....	....	Great Pond jointly with Randolph and Braintree
1905 Muschopauge Pond (See Rutland)	....	....	....	Muchopauge Pond Jointly, see Rutland
....	....	....	....	Wright and Ashley Ponds A = 0.45 D.A. = 2.58 M.G. = 1509
....	1912 Manhan River White Res. A = 0.20 D.A. = 4.00* M.G. = 650 1917 New Intake Res. D.A. = 13.0* M.G. = 1.0	....	1936 Fomer Res. renamed Carmody Res. High-service Res. renamed Hugh McLean Res.	Lower Whiting Street Res. Upper Whiting Street Res. Manhan River Supply Carmody Res. Manhan River Supply White Res. and New Intake Res.

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Holyoke (Continued)			1890 Upper Whiting Street Storage Res. A = 0.19 D.A. = 1.47* M.G. = 479 (Total D.A. = 1.66*)	
Hopedale Milford Water Co.	....	....	1881 Wells and Charles River	....
Hudson	....	....	1884 Gates Pond A = 0.12 D.A. = 0.58 M.G. = 100	1897 New dam on Gates Pond A = 0.13 D.A. = 0.27 M.G. = 350 1897 Swamp diverted 1898 Fosgate Brook D.A. = 0.16
Hull	....	....	1882 Hingham Water Co.	....
Huntington Huntington Fire Dis.	....	....	....	1899 Cold Brook Res. D.A. = 0.94 M.G. = 1.3 1891 Springs
Ipswich	....	....	....	1894 Dow's Brook Res. A = 0.03 D.A. = 0.88 M.G. = 55 Bull Brook Intake D.A. = 3.64
Lancaster 1797 Lancaster Aqueduct Co. 1871 Union Aqueduct Co. 1885 Town	Springs	Springs	1885 Clinton Supply	....
Lawrence	....	1875 Filter gallery 1875 Merrimack River D.A. = 4634	....	1893 River water filtered
Lee Berkshire Water Co.	....	....	1881 Lower Codding Brook Res. D.A. = 2.51* M.G. = 2.0 1881 Upper Codding Brook Res. A = 0.04 D.A. = 0.67*	1891 Laurel Lake (Emergency) 1893-1894 Upper Codding Brook Dam raised twice A = 0.04 D.A. = 0.67* M.G. = 71 1900 Basin Pond Brook Res. D.A. = 8.20

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
				Hugh McLean Res. Crystal Springs (Few houses)
....	....	....	....	Wells and Charles River filtered
....	....	....	....	Gates Pond A=0.13 D.A.=0.27 M.G.=350 Fosgate Brook D.A.=0.16
....	....	....	....	Hingham Water Co.
1908 Ground water supply	....	....	....	Cold Brook Res. Ground water supply (Auxiliary)
....	....	1923 Flashboards added A=0.03 D.A.=0.88 M.G.=61 1926 New Basin D.A.=3.65 M.G.=3.0	....	Dow's Brook Res. A=0.03 D.A.=0.88 M.G.=61 Bull Brook Res. D.A.=3.65 M.G.=3.0
....	....	....	....	Clinton Supply
....	....	....	....	Merrimack River filtered D.A.=4452
1905 Venetti Res. on Codding Brook D.A.=2.51* M.G.=0.7	....	....	....	Lower Codding Brook Res. Upper Codding Brook Res. Venetti Res. Basin Pond Brook Res.

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Leicester Cherry Valley and Rochdale Water District	....	....	....	....
Lenox Lenox Water Co.	....	1874-1875-1877 Ravine Reservoirs M.G. = 0.025 1874-1875 Woolsey Reservoir	1889 New Woolsey Res. M.G. = 0.5	1895 Lower Root Res. D.A. = 0.70
Aspinwall Water Co. (Aspinwall Hotel)	....	....	....	....
Leominster	....	1876 Morse Mill Pond D.A. = 0.28* 1873 Haynes Res. A = 0.09 D.A. = 0.49 M.G. = 140 1873 Distributing Reservoir A = 0.01 D.A. = 1.91* M.G. = 9	....	1891 Morse Res. A = 0.02 D.A. = 0.28* M.G. = 49 1896 Fall Brook Res. A = 0.13 D.A. = 1.45 M.G. = 419
Lincoln	....	1874 Sandy Pond (See Concord)	....	....
Longmeadow	....	....	....	1895 Cooley Brook D.A. = 0.50 M.G. = .065
Lowell	....	1872 Merrimack River 1872 Filter gallery 1876 Surface filter	....	1892 72% Merrimack River 1895 34% Merrimack River 1892 Ground water supply 28% 1895 Ground water 66%
Ludlow 1873 Ludlow Mfg. Co.	....	1873 Springfield Supply (Ludlow Res.)	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	1911 Dug wells	....	....	Ground water supply
	1911 Henshaw Pond filtered A = 0.55 D.A. = 0.79 M.G. = 500			Henshaw Pond filtered A = 0.55 D.A. = 0.79 M.G. = 500
1908 Lower Root Dam raised A = 0.02 D.A. = 0.70 M.G. = 65	1914 Laurel Lake (Emergency)	....	....	Ravine Res. Woolsey Res. Lower Root Res. Upper Root Res. M.G. = 0.3
1902-1906 Ground water and Yokum River D.A. = 0.1 M.G. = 0.2	....	....	1933 Hotel burned, supply abandoned	....
....	....	1925 Hale Brook Diversion (Emergency)	....	Morse Res. Haynes Res.
		1925 Wilder Brook Diversion (Emergency) D.A. = 0.26		Distributing Res. and Hale Brook Fall Brook Res. and Wilder Brook
		1930 No-Town Res. A = 0.37 D.A. = 5.35* M.G. = 681 Goodfellow Pond D.A. = 5.35* Symonds Pond D.A. = 5.35* M.G. = 8.0		No-Town Res. Goodfellow Pond Symonds Pond
....	....	....	....	Sandy Pond (See Concord)
....	....	1922 Springfield Supply (Little River)	....	Springfield Supply (Little River)
....	Additions to ground water supply	....	....	Ground water supply
....	....	....	....	Springfield Supply (Ludlow Res.)

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Lynn 1878 Saugus 1926 Lynnfield Water District	....	1871-1878 Breed's Pond A=0.09 D.A.=1.07 M.G.=231 1872 Birch Pond D.A.=0.68	1885 Birch Pond Dam Raised A=0.13 D.A.=0.68 M.G.=381 1884 Hawkes Brook and Penny Brook Diverted to Birch Pond 1889 Glenn Lewis Res. on Penny Brook A=0.06 D.A.=0.36 M.G.=100 1889 Walden Pond on Penny Brook A=0.30 D.A.=1.67 M.G.=311 1882 Ground water pumped to Breed's Pond	1897 Hawkes Pond A=0.12 D.A.=1.86 M.G.=348 1893 Saugus River to Walden Pond D.A.=16.64 1898 Saugus River to Hawkes Pond D.A.=10.58
Manchester	....	....	....	1892 Ground water supply
Marlborough	....	....	1883 Lake Williams A=0.11 D.A.=0.45 M.G.=300	1893 North Branch of Millham Brook 1895 Millham Brook Res. A=0.10 D.A.=3.54 M.G.=450
Maynard	....	....	1889 White Pond A=0.09 D.A.=0.66 M.G.=190 Pipe line laid with open joints to collect ground water also	....
Methuen 1875 Supplied by Lawrence 1894 Town	....	1875 Merrimack River, Lawrence Supply	....	1894 Ground water supply
Middleton Danvers Supply	....	1876 Danvers Supply	....	....
Milford and Hopedale Milford Water Co.	....	....	1881 Ground water supply and Charles River	....
Millbury 1925 Maple Hillside Water Co. 1936 Maple Hillside Water District	....	....	....	....
Monroe Deerfield Glassine Paper Co. 1935 Monroe Water Dis.	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
1905 Glenn Lewis Res. flooded by New Walden Pond Dam Walden Pond Dam raised A=0.38 D.A.=1.75 M.G.=1998	1916 Breed's Pond Dam Raised A=0.33 M.G.=1600 1918 Ipswich River D.A.=43.12	....	....	Breed's Pond Birch Pond Hawkes Pond Walden Pond Saugus River (Emergency) Ipswich River
1909 Gravel Pond A=0.07 D.A.=0.20 M.G.=320	....	....	....	Ground water supply Gravel Pond
....	....	....	....	Lake Williams Millham Brook Res
....	Pipe line relaid with tight joints	....	....	White Pond A=0.09 D.A.=0.66 M.G.=190
....	Direct from Spicket River	....	....	Ground water supply Spicket River (Emergency)
....	....	....	....	Danvers Supply
....	....	....	....	Ground water supply and Charles River
....	....	1925 Ground water supply	1935 Worcester Supply	Worcester Supply
....	....	Phelps Brook Reservoir D.A.=0.89 M.G.=0.05	1937 Upper Res. Phelps Brook D.A.=0.89* M.G.=0.05	Upper Res. Phelps Brook Phelps Brook Reservoir

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Monson	....	....	....	1895 Ground water supply
Montague 1887 Turners Falls Fire Dis. 1896 Millers Falls Fire and Water District (Montague and Erving) 1909 Lake Pleasant Water Dis. 1911 Montague Village (E. L. Bartlett)	....	....	1887 Lake Pleasant A=0.11 D.A.=1.78 M.G.=167	1896 Turners Falls Fire District Supply ....
Monterey Monterey Water Co.	....	....	....	....
Nantucket 1878 Wannacomet Water Co. 1913 Siasconset (Town)	....	1878 Wannacomet Pond A=0.01 D.A.=0.10 M.G.=25	....	....
Natick	....	1874 Dug Pond A=0.07 D.A.=0.89 M.G.=150	....	....
New Bedford and Acushnet Dartmouth Freetown (Small Part)	1869 Acushnet Res. A=0.47 D.A.=7.3 M.G.=300	....	1886 Little Quittacas Pond connected to Acushnet Res. by gravity A=0.50 D.A.=1.39 M.G.=300	1899 Pumping Station installed on Little Quittacas Pond. Great Quittacas Pond A=1.81 D.A.=11.42 M.G.=4990 tributary to Little Quittacas Pond
Newburyport Newbury (Small Part) Salisbury Ring's Island Water District 1881 Newburyport Water Co. 1898 City	....	....	1881 Ground water supply and Trout Brook	1893 Additional ground water supply
North Adams 1848 No. Adams Water Co. 1875 No. Adams Fire Dis. 1896 City	1848 Springs 1851 Notch Brook Reservoir D.A.=2.50 1861 Storage Res. M.G.=6.0	1884 Ground water supply	1889 Broad Brook Res. D.A.=6.24 M.G.=0.02 1890 James Brook Res. D.A.=1.51 M.G.=0.025	1896 Notch Brook Res. A=0.02 D.A.=2.50 M.G.=94

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
1904-1910 Ingalls Brook Intakes D.A. = 0.75*	1912 Conant Brook Res. Immediately failed D.A. = 6.28* M.G. = 30	1921 New Conant Brook Res. D.A. = 6.28 M.G. = 30	....	Ground water supply Ingalls Brook Intakes (Emergency)
		1925 Additional ground water supply		Conant Brook Res. (Emergency)
1909 Turners Falls Fire District Supply	....	....	....	Lake Pleasant A = 0.11 D.A. = 1.78 M.G. = 167
....	1911 Ground water supply	....	....	Ground water supply
....	1917 Reservoir D.A. = 0.18 M.G. = 0.02	....	....	Reservoir D.A. = 0.18 M.G. = 0.02
....	1911 and 1913 Ground water supply	Additional ground water supply	Additional ground water supply	Wannacomet Pond (Emergency) Ground water supply
1903 Ground water supply Connection to Lake Cochituate (Emergency)	....	....	....	Ground water supply Lake Cochituate (Emergency only)
....	....	Assawompsett and Pocksha Ponds A = 4.20 D.A. = 13.17 M.G. = 8900 See Chap. 400 Acts 1924 (See Taunton)	....	Acushnet Res. (Emergency) Little Quittacas Pond Great Quittacas Pond Assawompsett and Pocksha Ponds (See Taunton)
1903-1906 Additional ground water supply 1908 Lower Artichoke Reservoir A = 0.27 D.A. = 6.00* M.G. = 50	1914 Upper Artichoke Reservoir A = 0.23 D.A. = 4.00* M.G. = 225	....	....	Ground water supply Lower Artichoke Reservoir Upper Artichoke Reservoir
....	1914-1915 Mt. Williams Res. A = 0.07 D.A. = 1.75 M.G. = 201	....	Ground water not used since 1932	Notch Brook Res. Broad Brook Res. James Brook Res. Mt. Williams Res.

*Total

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Northampton	....	1871 Lower Res. Roberts Meadow Brook D.A. = 10.6 M.G. = 4.0 1879 Dam Raised M.G. = 6.0	1883 Upper Res. Roberts Meadow Brook M.G. = 16.5	1894 Middle Res. A = 0.04 D.A. = 10.5 M.G. = 84
North Andover	....	....	....	1898 Great Pond A = 0.88 D.A. = 5.26 M.G. = 4455
Northborough	....	....	1882 Cold Harbor Brook Lower Res. A = 0.01 D.A. = 2.36 M.G. = 30 1882 Cold Harbor Brook Upper Res. (Mill Pond)	....
Northbridge 1889 Whitin Machine Works 1936 Town (Part Only)	1870 Ground water supply	Mill supply only	1889 Ground water supply	1891-1896 Ground water supply
North Brookfield	....	....	....	1893 Doane Pond A = 0.05 D.A. = 1.40 M.G. = 54 1893 North Pond A = 0.11 D.A. = 0.31 M.G. = 350 1893 North Brook and Canal D.A. = 0.33
Northfield 1879 Northfield Schools, Incorporated East Northfield Water Co. (Northfield Schools, Inc. Supply) 1900 Northfield Water Co.	....	....	....	Ground Water and Brook 1900 Minot Brook Res. D.A. = 0.47 M.G. = 0.30

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
1904-1905 Mountain Street Res. A = 0.11 D.A. = 0.75 M.G. = 336 Avery Brook Res. A = 0.01 D.A. = 7.53 M.G. = 24	....	....	....	Upper Res. Roberts Meadow Brook (Emergency) Middle Reservoir Roberts Meadow Brook (Emergency) Mountain Street Res. Avery Brook Res.
....	....	....	....	Great Pond A = 0.88 D.A. = 5.26 M.G. = 4455
....	....	....	1935 Upper Res. abandoned	Cold Harbor Brook Res. A = 0.01 D.A. = 2.36 M.G. = 30
1902 Cook Allen Res. No. 4 A = 0.01 D.A. = 1.2* M.G. = 50 1907 Reservoir No. 6 A = 0.03 M.G. = 50 1910 Reservoir No. 5 A = 0.08 D.A. = 0.7 M.G. = 200	1917-1918 Ground water supply	1922 Ground water supply	....	Ground water supply
....	....	....	....	Doane Pond A = 0.05 D.A. = 1.40 M.G. = 54 North Pond D.A. = 0.31 M.G. = 350 North Brook and Canal D.A. = 0.33
1904-1907 Lower Res. on Louisiana Brook D.A. = 0.45* M.G. = 0.375	1915 Filter	....	Ground water practically abandoned 1933-1934 Upper Res. on Louisiana Brook A = 0.01 D.A. = 0.45* M.G. = 30	Lower Res. on Louisiana Brook Upper Res. on Louisiana Brook
....	1914 Warwick Brook (Emergency)	....	....	Minot Brook Res. D.A. = 0.47 M.G. = 0.30

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Norwood	....	....	1885 Buckmaster Pond A=0.05 D.A.=0.40 M.G.=400	....
Orange 1873 New Home Sewing Machine Co. 1893 Town	....	1873 Ground water supply	....	1893 Coolidge Brook Res D.A.=1.38 M.G.=2.0 1893 North Pond A=0.21 D.A.=0.66 M.G.=357 (Used for power to pump water) 1895 Ground water supply
Palmer 1886 Palmer Water Co. 1921 Palmer Fire District No. 1	....	....	1886 Upper Graves Brook Res. A=0.01 D.A* M.G.=6.0 1886 Lower Graves Brook Res. D.A.=0.50* M.G.=1.5	....
Bondsville Water Company	....	....	....	....
Several Small Water Companies	....	....	....	....
Peabody 1799 Salem and Danvers Aqueduct Co. 1873 City	1799 Ground water supply 1797 Brown's Pond A=0.04 D.A.=0.45 M.G.=62 1797 Spring Pond A=0.10 D.A.=0.49 M.G.=470 1797 Tapley Brook Res. A=0.03 D.A.=0.32 M.G.=30	....	....	....
Pembroke	....	....	....	....
Pittsfield 1855 Pittsfield Fire District 1891 City	1855 Ashley Lake Raised 1867 D.A.=0.55 1855 Lower Ashley Reservoir D.A.=1.75*	1875 Sacket Brook Reservoir D.A.=2.20	1886 Ashley Lake Dam Raised 2 ft.	1892 Hathaway Brook Reservoir D.A.=1.05* 1895 Mill Brook Res. D.A.=1.17

*Total

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	1911-1920 Ground water supply	1921 Ground water supply	....	Buckmaster Pond Ground water supply
....	....	....	North Pond practically abandoned	Coolidge Brook Res. D.A. = 1.38 M.G. = 2.0 Ground water supply
....	1916 Upper dam raised 6 feet M.G. = 18	1922 Ground water supply	....	Upper Graves Brook Res. A = 0.01 D.A.* M.G. = 18 Lower Graves Brook Res. D.A. = 0.50* M.G. = 1.5 Ground water supply
1908 Ground water supply	....	....	....	Ground water supply
....	....	....	....	Ground water supplies
1906 Suntaug Lake A = 0.19 D.A. = 0.57 M.G. = 713	1912 Ground water 1918 Cedar Pond Brook D.A. = 1.50	1927 Ipswich River (See Lynn)	....	Spring Pond Tapley Brook Res. Cedar Pond Brook (Emergency) Suntaug Lake Ipswich River pumped to Suntaug Lake (See Lynn)
....	1913 Brockton Supply	....	....	Brockton Supply
1902 New Ashley Lake Dam A = 0.17 D.A. = 0.55* M.G. = 191 1907-1908 New Lower Ashley Reservoir A = 0.01 D.A. = 1.75* M.G. = 23	1912 Farnham Res. A = 0.06 D.A. = 0.60* M.G. = 516 Roaring Brook D.A. = 3.46**	....	1937 Sand Wash Brook Res. A = 0.1 D.A. = 1.43** M.G. = 265	Ashley Lake Lower Ashley Res.

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Pittsfield (Continued)				
Junction Water Co. (Noble) (No. Adams Junction)	....	....	....	1890 Reservoir on Brattle Brook
Plymouth 1797 The Proprietors of the Plymouth Aqueduct	1797 Town Brook 1855 Little South Pond A=0.11 D.A.=0.24 M.G.=157 1855 Great South Pond A=0.47 D.A.=1.39 M.G.=698 1855 Boot Pond A=0.07 D.A.=0.89 M.G.=168	1879 Lout Pond A=0.03 D.A.=0.14 M.G.=12	....	....
Randolph	....	....	1888 Great Pond (See Braintree)	....
Rockland	....	....	1887 Big Sandy Bottom Pond (See Abington)	....
Rockport	....	....	....	1895 Cape Pond A=0.06 D.A.=0.42 M.G.=144
Russell	....	....	....	....
Rutland	....	....	....	1896 Muschopauge Pond A=0.10 D.A.=0.60 M.G.=465

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
1907 New Sacket Brook Reservoir D.A. = 2.20 M.G. = 2.0				Sackett Brook Res Hathaway Brook Reservoir Mill Brook Res. Farnham Res.
1908 New Hathaway Brook Res. D.A. = 1.05* M.G. = 1.0				Onota Lake (Emergency)
1908 New Mill Brook Reservoir D.A. = 1.17 M.G. = 14				Sand Wash Brook Reservoir
Onota Lake (Emergency) A = 1.04 D.A. = 9.67 M.G. = 4629				
....	....	....	....	Reservoir on Brattle Brook
....	....	....	....	Little South Pond Great South Pond Boot Pond Lout Pond (Emergency)
....	....	....	....	Great Pond—jointly with Braintree and Holbrook
....	....	....	....	Big Sandy Bottom Pond (See Abington)
....	....	1926 and 1930 Ground water supply	1938 Ground water supply	Cape Pond Ground water supply
....	1911 Black Brook Res. D.A. = 3.17 M.G. = 1.0	....	1931-1934 Ground water supply	Black Brook Res. Ground water supply
....	....	....	....	Muschopauge Pond A = 0.11 D.A. = 0.60 M.G. = 465 (Jointly with Holden)

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Salem and Beverly 1799 Salem and Danvers Aqueduct Co. 1866 City 1913 Salem and Beverly Water Supply Board	1799 Ground water supply 1850 Spring Pond (See Peabody) 1865 Brown's Pond (See Peabody) 1868 Wenham Lake A=0.39 D.A.=2.18 M.G.=2000 Also supplied by Salem to Beverly	....	1887 Independent Works for Beverly Wenham Lake	1895 Longham Res. A=0.14 D.A.=3.65 M.G.=55
Saugus	....	1878 Lynn Water Supply	....	....
Scituate 1893 Scituate Water Co. 1932 Town	....	....	....	....
Shelburne and Buckland 1885 Aqueduct Companies 1911 Shelburne Falls Fire District	1885 Fire District	....	1885 Ground water supply Aqueduct Companies	....
Southampton 1900 Mt. Spring Water Co. 1931 Town	....	....	....	....
Southborough 1924 Fayville Fire and Water District 1930 Town	....	....	....	....
Southbridge Southbridge Water Supply Co.	....	1880 Reservoir No. 1 Nuisance Brook A=0.01 D.A.=0.26* M.G.=9.1	1888 Reservoir No. 2 Nuisance Brook D.A.=0.10* M.G.=6.5	1894 Hatchet Brook Reservoir No. 3 A=0.03 D.A.=2.95* M.G.=85
South Hadley South Hadley Fire District No. 1	....	1872 Buttery Brook Res. D.A.=0.50 M.G.=4.0	....	1891 Leaping Well Res. A=0.01 D.A.=0.62 M.G.=30
South Hadley Fire District No. 2	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	1914 Ipswich River pumped to Wenham Lake D.A. = 99.00	....	....	Wenham Lake A = 0.39 D.A. = 2.18 M.G. = 2000 Longham Res. A = 0.14 D.A. = 3.65 M.G. = 55 Ipswich River D.A.—99.00
....	....	....	....	Lynn Water Supply
1901-1904-1910 Ground water supply	1913 Ground water supply	1926-1927-1930 Ground water supply	1933-1934 Ground water supply	Ground water supply
	1913 Old Oaken Bucket Pond A = 0.02 D.A. = 4.00 M.G. = 60			Old Oaken Bucket Pond A = 0.02 D.A. = 4.00 M.G. = 60
....	1912 Intake Res. Fox Brook D.A. = 0.98* M.G. = 0.55	1929 Storage Res. Dam raised 5 ft. D.A. = 0.50* M.G. = 12	....	Intake Res. Fox Brook D.A. = 0.98* Total M.G. = 0.50
	1912 Storage Res. Fox Brook D.A. = 0.50* M.G. = 7.0			Storage Res. Fox Brook D.A. = 0.50* M.G. = 12
1900 Ground water supply	....	....	1931 Holyoke Supply (Manhan System)	Holyoke Supply (Manhan System)
....	....	1924 Sudbury Res. (See Metropolitan)	....	Sudbury Res. (See Metropolitan)
1906 Hatchet Brook Reservoir No. 4 A = 0.1 D.A. = 2.43* M.G. = 185	Reservoir No. 1 used for ice-cutting	1925 Hatchet Pond Dam Raised A = 0.04 D.A. = 0.52* M.G. = 98	1937 Hatchet Brook Reservoir No. 5 A = 0.05 D.A. = 1.45* M.G. = 150	Hatchet Brook Reservoir No. 3 Hatchet Brook Reservoir No. 4 Hatchet Pond Hatchet Brook Reservoir No. 5
....	....	....	....	Buttery Brook Res.
				Leaping Well Res.
....	1911, 1915, 1918 Ground water supply	....	1932 Elmer Brook (North Branch) D.A. = 1.60	Ground water supply Elmer Brook (North Branch) D.A. = 1.60

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Southwick	....	....	....	....
Spencer 1883 Spencer Water Co. 1884 Town	....	....	1883 Shaw Pond A=0.12 D.A.=0.60 M.G.=200±	....
Springfield 1843 Charles Stearns 1848 Springfield Aqueduct Co. 1860 City Aqueduct Co. 1873 City Ludlow System supplies Ludlow Wilbraham Little River System supplies Agawam East Longmeadow Longmeadow Southwick West Springfield (In Emergency)	1790 Ground water 1843 Lombard Res. M.G.=0.126 1848 Hayward Res. Stebbins Res. Chapin Res. Worthington Res. 1860 Ground water 1865 Upper Van Horn Res. M.G.=73 Lombard Res. reconstructed M.G.=9	1872 Garden Brook, abandoned in 1873 1873-1874 Connecticut River at Brightwood (filtered), abandoned in 1875 1875 Ludlow Res. Broad and Axe Factory Brooks A=0.70 D.A.=7.27 M.G.=2093 1875 All but Ludlow Res. abandoned	1890 Higher Brook to Ludlow Res. D.A.=1.75	1891 Jabish Brook and Canal D.A.=11.29 to Ludlow Res.
Stockbridge Stockbridge Water Co.	1851 Ground water 1862 Reservoir on Bear Mountain	....	....	1892 Lake Averic A=0.06 D.A.=1.80 M.G.=250
Hill Water Company	....	....	1885 Ground water supply	....
Stoughton 1886 Stoughton Water Co. 1892 Town	....	....	1886 Ground water supply	1893 Ground water supply 1893 Filter Muddy Pond Brook 1893-1906 Direct from Brook
Sturbridge 1876 Sturbridge Aqueduct Co. 1903-1905 Fiskdale Mills 1933 Town	....	1876 Ground water supply	....	....
Sunderland Sunderland Water Co.	....	....	1883 Saw Mill Brook Reservoir D.A.=0.40	....
Taunton	....	1876 Ground water supply. Taunton River direct	1883-1887-1889 Ground water supply Taunton River direct	1894 Elder's Pond A=0.22 D.A.=0.53 M.G.=693 1894 Assawompsett Pond (See New Bedford)

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	1930 Springfield Supply (Little River System)	Springfield Supply (Little River System)
....	....	....	....	Shaw Pond A=0.12 D.A.=0.60 M.G.=200±
1908-1909 Little River Intake Res. D.A.=48.0* M.G.=52	....	1930 Cobble Mountain Res. A=1.63 D.A.=45.80* M.G.=22,225	....	Ludlow Res. A=0.70 D.A.=20.31 M.G.=2093
1908-1909 Borden Brook Res. A=0.34 D.A.=7.95* M.G.=2500				Little River Intake Res. Borden Brook Res. Cobble Mountain Res.
....	....	....	....	Reservoir on Bear Mountain Lake Averic
....	....	....	....	Ground water supply
1906 Filter abandoned 1906 Muddy Pond D.A.=1.00 M.G.=5.0	....	....	....	Muddy Pond D.A.=1.00 M.G.=5.0
1903-1905 Quinebaug River	....	....	1933 Ground water supply	Ground water supply
....	....	1929 Reservoir Rebuilt D.A.=0.40 M.G.=0.25	....	Saw Mill Brook Res. D.A.=0.40 M.G.=0.25
....	....	See Chapter 400, Acts 1924	....	Elder's Pond A=0.22 D.A.=0.53 M.G.=693 Assawompsett Pond (See New Bedford)

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Wakefield 1883 Wakefield Water Co. 1903 Town	....	....	1883 Crystal Lake A=0.13 D.A.=0.90 M.G.=350	....
Wareham Wareham Fire District	....	....	....	....
Onset Fire District	....	....	....	1894 Jonathan Pond A=0.02 D.A.=0.23 M.G.=30
Wayland	....	1878 Ground water supply Snake Brook Reservoir A=0.02 D.A.=0.67 M.G.=16	....	....
Webster 1881 H. L. Slater 1894 Town	....	....	1881 Lake Chaubunagungamaug A=1.94 D.A.=9.73	1893 Ground water supply
Westborough	....	1879 Sandra Pond A=0.08 D.A.=1.05 M.G.=45	1887 Pond divided into two basins Filter Dam	....
West Boylston Pinecroft Water Dis.	....	....	....	....
West Bridgewater	....	....	....	....
Westfield	....	1874 Montgomery Reservoir A=0.06 D.A.=2.06* M.G.=184 1874 Tekoa Res. D.A.=2.70* M.G.=4.0	....	1899 Tillotson Brook Intake Res. D.A.=6.00* M.G.=3.1
Westhampton Westhampton Water Co.	....	....	....	1894 Reservoir on Brook D.A.=0.60 M.G.=.036
West Springfield 1875 West Springfield Aqueduct Co. 1892 Town	....	1875 Darby Brook Res. D.A.=0.35 M.G.=10	....	1893-1895 Ground water supply
Weymouth	....	....	1885 Great Pond A=0.45 D.A.=3.00 M.G.=493	....
Whitman 1883 Town 1905 Supplied by Brockton	....	....	1883 Ground water supply	1891 Ground water supply Connection to Pond

*Total 2.70

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	1930 Ground water supply	1931 Ground water supply	Crystal Lake Ground water supply
1908 Ground water supply	....	1925 Ground water supply	1933-1935 Ground water supply	Ground water supply
....	....	....	....	Jonathan Pond A = 0.02 D.A. = 0.23 M.G. = 30
....	....	1925 Ground water supply	1933 Ground water supply	Ground water supply
....	....	....	....	Ground water supply
....	All water drawn from Lower Basin since 1917	....	....	Sandra Pond A = 0.08 D.A. = 1.05 M.G. = 45
....	....	....	1933 Worcester Supply	Worcester Supply
....	1911 Brockton Supply	....	....	Brockton Supply
1902 Japhet Brook Res. D.A. = 0.41 M.G. = 0.2	Tillotson Brook Res. changed to Winchell Reservoir	1929 New Granville Res. A = 0.12 D.A. = 6.00* M.G. = 630	....	Montgomery Res. Tekoa Res. Winchell Res. Japhet Brook Res. New Granville Res.
....	....	....	....	Reservoir on Brook D.A. = 0.60 M.G. = .036
1907-1908 Lower Res. Bear Hole Brook D.A. = 3.05*	1912 Lower Res. Dam raised M.G. = 65	....	1937 Test for ground water supply	Lower Res. Bear Hole Brook D.A. = 3.05* Total M.G. = 65
Upper Res. Bear Hole Brook M.G. = 4.0	Industrial use of Darby Brook Res. at Railroad Yards			Upper Res. Bear Hole Brook D.A.* M.G. = 4.0
....	....	....	....	Great Pond A = 0.45 D.A. = 3.00 M.G. = 493
1905 Brockton Supply	....	....	....	Brockton Supply

TABLE 2C—MASSACHUSETTS SURFACE WATER

Municipality or District Owning Sources of Supply	Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900
Wilbraham	....	....	....	....
Williamsburg	....	....	....	....
Williamstown				
1860 Williams Aqueduct Co.	1796 Ground water supply 1859 Ground water supply	....	....	....
1847 Williamstown Water Co.	1848 Ground water supply	....	....	....
1885 1887 Greylock Institute Water Co.	....	....	1887 Green River	....
1892 Williamstown Water Co.	....	....	....	1892 Paul Brook Res. D.A.=0.52 1896 Flora Glen Two Reservoirs D.A.=0.72 M.G.=4.5
Winchester	....	1874 North Res. A=0.09 D.A.=0.50 M.G.=256	1881 South Res. started	1891 South Reservoir divided to form the Middle Reservoir A=0.13 D.A.=0.30 M.G.=188 1894 South Res. A=0.09 D.A.=0.47 M.G.=550 1899 Diversion of Dyke's Brook
Worcester	....	....	....	....

SUPPLIES AND DATES OF INSTALLATION.—*Continued.*

1901 to 1910	1911 to 1920	1921 to 1930	Since 1930	In use 1938
....	....	....	1929 Springfield Supply (Ludlow System)	Springfield Supply (Ludlow System)
1903 Lower Reservoir Unquomonk Brook D.A. = 0.90 M.G. = 0.57 1903 Upper Reservoir Unquomonk Brook M.G. = 9.1	....	....	....	Lower Reservoir Unquomonk Brook D.A. = 0.90 M.G. = 0.57 Upper Reservoir Unquomonk Brook M.G. = 9.1
....	....	....	....	Ground water supply
....	....	....	....	....
....	....	....	....	....
1905 Rattlesnake Brook Reservoir A = 0.07 D.A. = 0.53 M.G. = 0.92	....	Flora Glen Res. not in use in 1923	....	Paul Brook Res. D.A. = 0.52 Rattlesnake Brook Reservoir D.A. = 0.53 M.G. = 0.92
....	....	....	1938 Tests for ground water	North Res. South Res. Middle Res.
....	....	....	....	See Metropolitan Tabulation

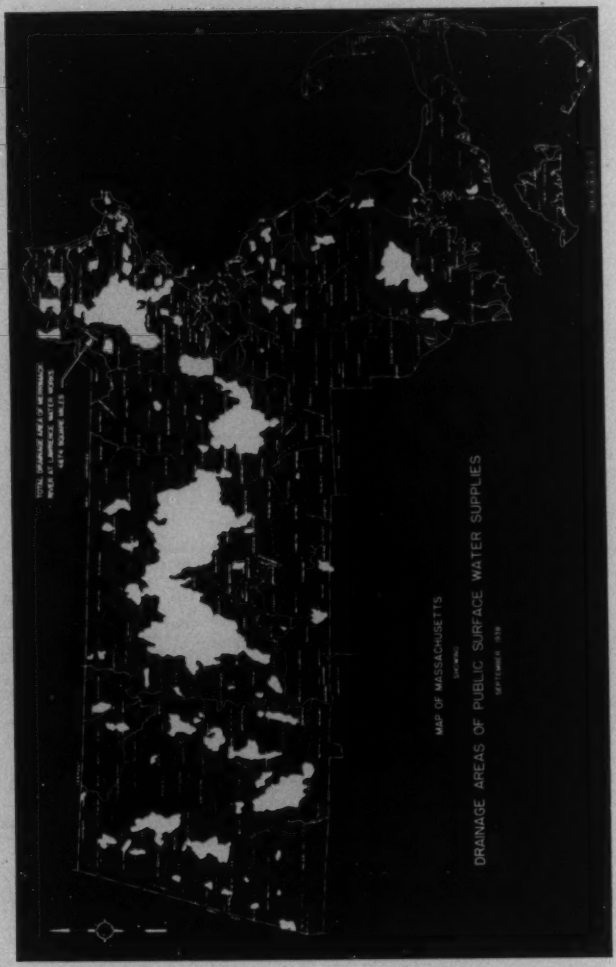

DRAINAGE AREAS OF PUBLIC SURFACE WATER SUPPLIES
MAP OF MASSACHUSETTS

FIGURE 1

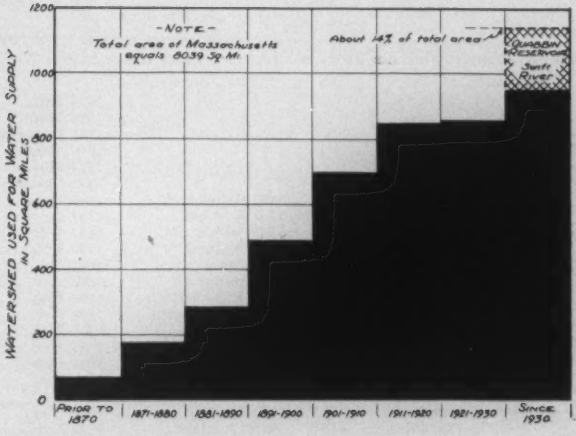


FIG. 2—WATERSHED AREAS OF PONDS AND RESERVOIRS USED FOR WATER SUPPLY PURPOSES IN MASSACHUSETTS.

Lake Pleasant Water Supply District
Erving (Millers Falls Fire and Water District)

New Bedford:
New Bedford, Dartmouth, Acushnet Fire and Water District

Salem and Beverly Water Supply Board:
Salem and Beverly

Shelburne (Shelburne Falls Fire District):
Shelburne Falls Village including part of the town of Buckland.

Springfield:
Springfield, Agawam, East Longmeadow, Longmeadow, Ludlow, Southwick, Wilbraham.

Worcester:
Worcester, Millbury (Maple Hillside Water District)
West Boylston (Pinecroft Water District)
Auburn (Woodland Park Water District)
Auburn (Elm Hill Water District—Not yet supplied).

Similar arrangements have been made between two or three agencies supplying ground water.

In Tables 2 A, B and C showing the installation of surface water supplies in Massachusetts alphabetical arrangement has been sacrificed somewhat to an arrangement according to works jointly used.

Location and Extent of Surface Water Supplies. In order that the proportion of the area of Massachusetts reserved for surface water supplies may be shown both geographically and diagrammatically Figures 1 to 4 are included in this paper.

TABLE 3A.—CONSTRUCTION AND RECONSTRUCTION OF SURFACE WATER SUPPLY WORKS.

						1895	Barre
						1894	Boston
						1897	Cambridge
						1896	Cheshire
						1893	Chester
						1893	Chicopee
				1887	Abington &	1894	Dalton
				1887	Rockland	1893	Danvers
				1883	Adams	1899	Falmouth
				1890	Andover	1893	Fitchburg
				1887	Athol	1891	Haverhill
				1885	Boston	1896	Haverhill
				1889	Brookfield	1897	Holyoke
		1872	Arlington	1887	Cambridge	1899	Holyoke
		1873	Adams	1882	Clinton	1897	Hudson
		1880	Amherst	1886	Clinton	1899	Huntington
		1875	Athol	1884	Dalton	1894	Ipswich
		1875	Boston	1884	Danvers	1893	Lee
		1878	Boston	1883	Fitchburg	1894	Lee
		1879	Boston	1882	Gardner	1895	Lenox
		1880	Brockton	1885	Gloucester	1891	Leominster
		1876	Cheshire	1885	Gt. Barrington	1896	Leominster
		1877	Chicopee	1888	Gt. Barrington	1897	Lexington
		1874	Concord &	1884	Haverhill	1895	Longmeadow
		1874	Lincoln	1886	Hingham	1893	Lynn
		1876	Danvers	1889	Hinsdale	1898	Lynn
		1874	Fall River	1888	Holbrook	1895	Marlborough
		1872	Fitchburg	1883	Holyoke	1899	New Bedford
		1880	Fitchburg	1890	Holyoke	1896	No. Adams
1870	Ashburnham	1880	Hingham	1884	Hudson	1894	Northampton
1796	Boston	1873	Holyoke	1881	Lee	1898	No. Andover
1848	Boston	1874	Lenox	1885	Lynn	1893	No. Brookfield
1864	Boston	1873	Leominster	1889	Lynn	1900	Northfield
1856	Cambridge	1871	Lynn	1883	Marlborough	1893	Orange
1870	Easthampton	1878	Lynn	1889	Maynard	1892	Pittsfield
1868	Gt. Barrington	1870	Malden	1887	Montague	1895	Rockport
1870	Greenfield	1870	Medford	1886	New Bedford	1896	Rutland
1802	Haverhill	1870	Melrose	1889	No. Adams	1895	Salem &
1867	Haverhill	1878	Nantucket	1890	No. Adams	1895	Beverly
1869	New Bedford	1874	Natick	1883	Northampton	1894	Southbridge
1861	No. Adams	1871	Northampton	1882	Northboro	1891	So. Hadley
1797	Peabody	1879	Northampton	1885	Norwood	1891	Springfield
1855	Pittsfield	1875	Pittsfield	1886	Palmer	1892	Stockbridge
1797	Plymouth	1879	Plymouth	1888	Quincy	1894	Taunton
1855	Plymouth	1880	Southbridge	1888	Southbridge	1894	Wareham
1850	Salem	1872	So. Hadley	1883	Spencer	1899	Westfield
1865	Salem	1875	Springfield	1890	Springfield	1894	Westhampton
1868	Salem	1878	Wayland	1883	Sunderland	1892	Williamstown
1843	Springfield	1879	Westborough	1883	Wakefield	1896	Williamstown
1865	Springfield	1875	W. Springfield	1881	Webster	1894	Winchester
1854	Worcester	1874	Winchester	1885	Weymouth	1892	Worcester
1864	Worcester	1871	Worcester	1883	Worcester	1896	Worcester

TABLE 3A.—CONSTRUCTION AND RECONSTRUCTION OF SURFACE WATER SUPPLY WORKS.—(Cont'd)

1905 Agawam
1904 Ashfield
1904 Athol
1909 Athol
1907 Attleboro
1909 Blandford
1904 Brockton
1908 E. Bridgewater
1902 Colrain
1907 Colrain
1909 Concord
1904 Dalton
1910 Dalton
1903 Deerfield
1907 Fitchburg
1909 Gardner
1903 Gloucester
1905 Gt. Barrington
1904 Greenfield
1905 Hadley
1909 Hadley
1905 Holden
1905 Lee
1911 Leicester
1908 Lenox
1905 Lynn
1909 Manchester
1904 Monson
1910 Monson
1908 Newburyport
1904 Northampton
1905 Northampton
1902 Northbridge
1910 Northbridge
1904 Northfield
1907 Northfield
1906 Peabody
1902 Pittsfield
1906 Southbridge
1908 Springfield
1909 Springfield
1906 Stoughton
1902 Westfield
1907 W. Springfield
1908 W. Springfield
1905 Whitman
1903 Williamsburg
1908 Metropolitan

1916 Achushnet
1912 Ashburnham
1912 Athol
1911 Attleboro
1911 Blackstone
1912 Braintree
1912 Buckland
1912 Chester
1914 Clinton
1915 Clinton
1916 Dalton
1919 Dalton
1913 Egremont
1915 Fitchburg
1915 Groveland
1920 Hanson
1912 Holyoke
1917 Holyoke
1916 Lynn
1912 Monson
1917 Monterey
1914 Newburyport
1914 No. Adams
1915 No. Adams
1916 Palmer
1913 Pembroke
1912 Pittsfield
1911 Russell
1914 Salem &
1914 Beverly
1913 Scituate
1912 Shelburne
1911 W. Bridgewater
1912 W. Springfield
1911 Worcester

1924 Athol
1925 Brookline
1930 Blandford
1927 Chicopee
1926 Clinton
1927 Fitchburg
1930 Gloucester
1930 Hadley
1923 Ipswich
1926 Ipswich
1930 Leominster
1921 Monson
1929 Shelburne
1924 Southborough
1925 Southbridge
1930 Southwick
1930 Springfield
1929 Sunderland
1929 Westfield
1929 Wilbraham

1934 Adams
1934 Bellingham
1930 Braintree
1932 Cambridge
1937 Monroe
1933 Northbridge
1934 Northbridge
1937 Pittsfield
1937 Southbridge
1932 So. Hadley
1931 Metropolitan
1938 Metropolitan
1939 Metropolitan

TABLE 3B.—CONSTRUCTION AND RECONSTRUCTION OF GROUND WATER SUPPLY WORKS.

	Ashfield	1877	Agawam	1887	Abington &	1895	Adams	1902	Adams	1912	Acton	1923	Amesbury	1935	Attleboro
1806	Cambridge	1876	Arlington	1887	Rockland	1897	Amesbury	1904	Attleboro	1911	Amesbury	1927	Amesbury	1936	Barnstable
1837	Cambridge	1873	Attleboro		Adams	1895	Arlington	1910	Attleboro	1914	Amesbury	1929	Attleboro	1938	Barnstable
1830	Chicopee	1875	Brookline	1885	Amesbury	1892	Attleboro	1907	Avon	1911	Ashland		Auburn	1936	Bernardston
1845	Chicopee	1879	Brookline	1887	Amherst	1899	Billerica	1908	Avon	1919	Ashland	1925	Barnstable	1932	Billerica
1796	Danvers	1876	Cambridge	1883	Arlington	1891	Bradford	1906	Ayer	1920	Auburn	1926	Barnstable	1937	Bourne
1839	Danvers	1876	Cheshire	1882	Attleboro	1892	(Haverhill)	1909	Bedford	1912	Barnstable	1925	Bedford	1934	Bridgewater
1839	Danvers	1876	Lawrence	1890	Avon	1897	Braintree	1909	Bourne	1916	Billerica	1930	Bedford	1933	Chatham
1845	Grafton	1872	Lowell	1887	Ayer	1892	Bridgewater	1906	Bridgewater	1924	Billerica	1925	Belchertown	1935	Chatham
	Hopkinton	1880	Lynn	1887	Belmont	1895	Bridgewater	1907	Chelmsford	1916	Bourne	1923	Bourne	1935	Dedham
	Kingston		Medfield	1890	Bradford[1]	1891	Brookline	1908	Chelmsford	1912	Bridgewater	1927	Bourne	1935	Deerfield
1797	Lancaster	1876	Newton	1887	Braintree	1895	Brookline	1902	Cohasset	1920	Bridgewater	1925	Bridgewater	1932	Dracut
1855	Milford	1873	Orange	1888	Bridgewater	1893	Canton	1908	Cohasset	1912	Brookfield	1930	Brookfield	1934	Dracut
1848	North Adams	1876	Sturbridge	1889	Bridgewater	1894	Canton	1901	Dedham	1915	Brookfield	1927	Canton	1936	Dudley
1870	Northbridge	1876	Taunton	1883	Brookline		Cummington	1905	Dedham	1911	Brookline	1929	Chatham	1934	Georgetown
1799	Peabody	1879	Uxbridge	1889	Canton	1897	Dedham	1910	Douglas	1913	Chelmsford	1922	Chelmsford	1934	Gt. Barrington
1833	Plymouth	1873	Waltham	1886	Cohasset	1899	Dedham	1906	Dracut	1916	Cummington	1930	Deerfield[4]	1936	Harwich
1799	Salem		Warren	1887	Cohasset	1900	Dracut	1908	Dracut	1913	Dedham	1922	Dracut	1935	Lowell
1798	Springfield	1878	Wayland	1881	Dedham	1894	Fairhaven	1910	Dudley	1915	Dedham	1930	Dracut	1934	Marion
1860	Springfield	1872	W. Brookfield	1888	E. Bridgewater	1900	Fairhaven	1909	E. Brookfield	1911	Deerfield[4]	1929	Dudley		Marshfield
1851	Stockbridge	1873	W.	1887	Easton	1893	Falmouth	1909	Easthampton	1915	Deerfield[4]	1929	Dunstable	1933	Medfield
1838	W. Brookfield		Stockbridge	1885	Framingham	1899	Falmouth	1906	Edgartown	1920	Dudley	1930	Dunstable	1932	Methuen
1796	Williamstown	1880	Williamstown	1884	Franklin	1891	Foxborough	1910	Fairhaven	1918	Dunstable	1926	Duxbury	1934	Methuen
1848	Williamstown	1873	Woburn	1887	Franklin	1893	Grafton	1910	Franklin	1914	Duxbury	1923	E. Brookfield		Nantucket
1798	Worcester			1888	Gill	1897	Groton	1910	Grafton	1913	Gt. Barrington	1924	Easthampton	1931	Needham
				1886	Grafton	1891	Holliston	1910	Granville	1913	Greenfield	1927	Edgartown	1934	Needham
				1889	Grafton	1892	Hyde Park	1909	Gt. Barrington	1912	Groton	1922	Foxborough	1936	No. Reading
				1887	Hardwick	1900	(Boston)	1904	Hardwick	1911	Hardwick	1930	Foxborough	1934	Paxton
				1884	Hopkinton	1891	Kingston	1906	Hardwick	1913	Hardwick	1924	Franklin	1932	Provincetown
				1889	Hopkinton	1897	Kingston	1903	Hingham	1911	Leicester[5]	1929	Franklin	1938	Provincetown
				1885	Hyde Park[2]	1891	Leicester[3]		Holliston	1912	Littleton	1930	Grafton	1930	Reading
				1886	Kingston	1891	Lexington	1908	Huntington	1912	Lowell	1930	Hanover	1934	Reading
				1888	Kingston	1894	Lexington	1901	Lowell	1919	Lowell	1922	Hardwick	1938	Rockport
				1881	Lexington	1892	Lowell	1901	Manchester	1912	Marblehead	1924	Hardwick	1931	Russell
				1884	Lexington	1900	Lowell	1908	Marion	1915	Marion	1929	Hopkinton	1934	Russell
				1889	Malden	1892	Malden	1910	Marion	1911	Marshfield	1930	Hopkinton	1930	Scituate
				1888	Mansfield	1894	Malden	1901	Medfield	1920	Marshfield	1922	Kingston	1934	Scituate
				1885	Marblehead	1892	Manchester	1904	Merrimac	1913	Mattapoisett	1924	Leicester	1934	Sheffield
				1889	Marblehead	1895	Manchester	1902	Methuen	1911	Medway		Lowell	1933	Shrewsbury
				1888	Marshfield	1891	Marblehead	1910	Methuen	1918	Medway	1929	Marion	1934	Shrewsbury
				1890	Marshfield	1895	Marblehead	1904	Nantucket	1916	Merrimac	1927	Marshfield	1933	Sturbridge
				1889	Medfield	1900	Marshfield	1903	Natick	1911	Methuen	1930	Marshfield	1936	Sudbury

1. Haverhill
2. Boston
3. Water Supply District
4. Fire District
5. C. V. & R.
6. Fire District No. 2

1885 Middleboro
1881 Milford &
1881 Hopedale
1890 Milton
1885 Nahant
1890 Needham
1881 Newburyport
1890 Newton
1884 North Adams
1884 No. Attleboro
1889 Northbridge
1890 Oak Bluffs
1884 Quincy
1884 Revere
1885 Sharon
1885 Shelburne & Buckland
1884 Stockbridge
1885 Stockbridge
1886 Stoughton
1886 Sunderland
1888 Swampscott
1890 Swampscott
1889 Taunton
1887 Tisbury
1886 Ware
1885 Watertown
1884 Wellesley
1886 Wellesley
1890 Westminster
1883 Whitman
1888 Williamstown
1884 Winthrop

1893 Medford
1893 Melrose
1894 Methuen
1900 Methuen
1895 Millbury
1891 Millis
1895 Millis
1895 Monson
1897 Natick
1899 Needham
1900 Needham
1893 Newburypo t
1898 Newburyport
1892 Newton
1894 Newton
1891 Northbridge
1896 Northbridge
1895 Orange
1893 Provincetown
1898 Provincetown
1892 Revere
1895 Revere
1897 Sheffield
1900 Southampton
1893 Stoughton
1892 Swampscott
1895 Swampscott
1896 Uxbridge
1896 Walpole
1891 Waltham
1893 Ware
1891 Watertown
1893 Watertown
1893 Webster
1897 Wellesley
1896 Weston
1900 Weston
1893 W. Springfield
1895 W. Springfield
1891 Whitman
1896 Winchendon

1903 Needham
1903 Newburyport
1906 Newburyport
1909 Newton
1905 No. Attleboro
1909 Oak Bluffs
1906 Oxford
1908 Palmer
1909 Pepperell
1909 Plainville
1907 Provincetown
Salisbury
1901 Scituate
1910 Scituate
1901 Sharon
1906 Sharon
1903 Shirley
1906 Uxbridge
1908 Waltham
1905 Ware
1910 Ware
1908 Wareham
1901 Webster
1909 Webster
1903 Westford
1910 Weston
1901 Westwood
1910 Winchendon
1907 Woburn
1908 Woburn
1908 Wrentham
1910 Wrentham

1912 Methuen
1911 Montague
1911 Nantucket
1913 Nantucket
1914 Needham
1911 Newton
1917 Northbridge
1918 Northbridge
1912 Norton
1911 Norwood
1920 Norwood
1914 Oxford
Palmer
1914 Provincetown
1918 Provincetown
1915 Reading
1917 Reading
1914 Salisbury
1920 Salisbury
1913 Scituate
1911 Sharon
1914 Shirley
1915 Shrewsbury
1911 So. Hadley[6]
1918 So. Hadley[6]
1914 Sutton
1918 Sutton
1918 Walpole
1911 Ware
1914 Ware
1912 Warren
1920 Warren
1915 Wellesley
1913 W. Brookfield
1917 Westford
1920 Westford
1911 Worthington

1923 Mattapoisett
1924 Mattapoisett
1921 Methuen
1930 Methuen
1925 Millbury
1922 Millis
1930 Millis
1925 Monson
1924 Nantucket
1927 Nantucket
1924 Needham
1927 Newton
1922 Northbridge
1921 Norwood
1925 Oxford
1922 Palmer
1924 Provincetown
1928 Provincetown
Rockport
1926 Scituate
1927 Scituate
1923 Sharon
1930 Sharon
1923 Shrewsbury
1925 Shrewsbury
1927 Somerset
Sturbridge
1924 Uxbridge
1930 Wakefield
1925 Wareham
1928 Wareham
1922 Warren
1925 Wayland
1924 Webster
1926 Webster
1924 Wellesley
1927 Wellesley
1929 Weston
1922 W. Stockbridge
1925 Wilmington
1928 Wilmington
1927 Woburn
1929 Wrentham

1935 Tisbury
1934 Townsend
1931 Wakefield
1934 Wareham
1933 Wayland
1937 Weston
1932 Woburn
1931 Wrentham
1934 Wrentham
1931 Yarmouth
1933 Yarmouth

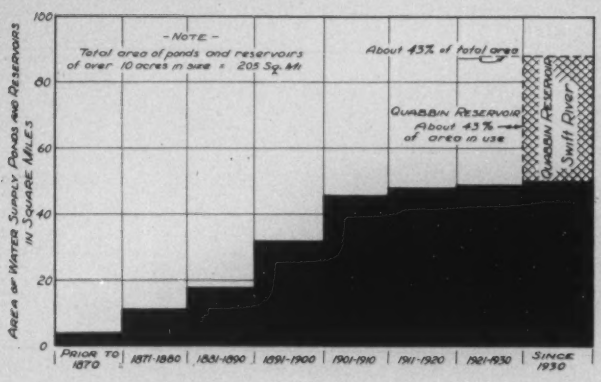


FIG. 3—INCREASE IN AREA USED FOR WATER SUPPLY STORAGE IN MASSACHUSETTS

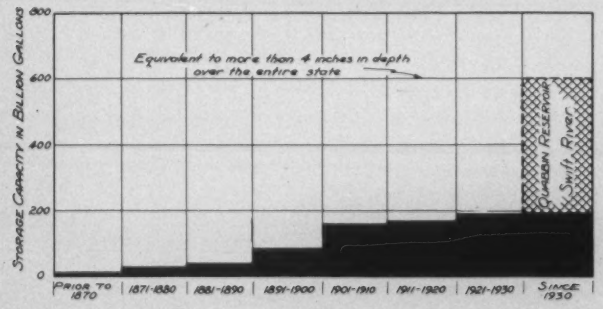


FIG. 4—RESERVATION AND CONSTRUCTION OF WATER WORKS STORAGE IN MASSACHUSETTS

Surface Water versus Ground Water. The choice between ground water and surface water supplies by municipalities initiating a public supply has been determined by the needs and available resources, but to a certain degree also by a desire for the generally greater safety and superior quality of ground waters. Once committed to a source of supply, additions have been made to it from time to time as the need required within the limitations of the available sources. Table 3 shows the initial and subsequent additions to the sources of supply of the several municipalities in Massachusetts in an attempt to demonstrate the trend in public water supply development as between surface and ground water sources.

Yield of Drainage Areas

It is possible with some degree of accuracy to estimate the safe or dependable yield of surface water supplies. Many years of measurements of precipitation and runoff offer records extending over wet and dry periods sufficient to give relations that, together with measurements of evaporation and other losses, permit reliable predictions to be made of the probable yield of any drainage area for which such records are available. In case precipitation records alone are available for a particular watershed, the relationship between rainfall and runoff for similar watersheds may be applied to the one in question. A second relationship must be introduced for the available storage. The evaporation from water surfaces and wet surfaces, such as swampy land, must be computed. The evaporation experiments of Fitzgerald at Chestnut Hill Reservoir furnish the basic data for such computations, and while it may be argued that actual evaporation may vary somewhat from his figures their use does not introduce an error exceeding the other errors of a safe yield calculation.

Precipitation. The amount of precipitation varies somewhat with the distance from the ocean or other large bodies of water and with the altitude of the observation station. Massachusetts in common with other parts of the Northern Atlantic Seabord is fortunate in having an abundant rainfall fairly well distributed through the several months of the year. Certain other parts of the country may have very low annual rainfall or receive the rainfall in a few months with long periods of drought each year.

The annual rainfall for Massachusetts, as a whole shown by long term records of seven well distributed recording stations, has averaged 44.61 inches over a period of 63 years.

Figure 5 prepared by Mr. George V. White shows by isoheytal lines the geographic variation of average annual rainfall in Massachusetts.

Records of rainfall at all the known recording stations in New England were compiled and first presented to this Association by the late X. H. Goodnough in 1915.[2] These records have been brought up to date periodically and similarly published.[3] The rainfall varies from year to year and much scientific effort has been expended to find an underlying law as to the periodicity of wet and dry cycles. More than a little interest is evidenced in attempts to correlate the sun spot frequency with subsequent rainfall. In the aforementioned paper

[2]This Journal 29 (1915), 237.
[3]This Journal 35 (1921), 228, 397; 40 (1926), 178; 44 (1930), 187.

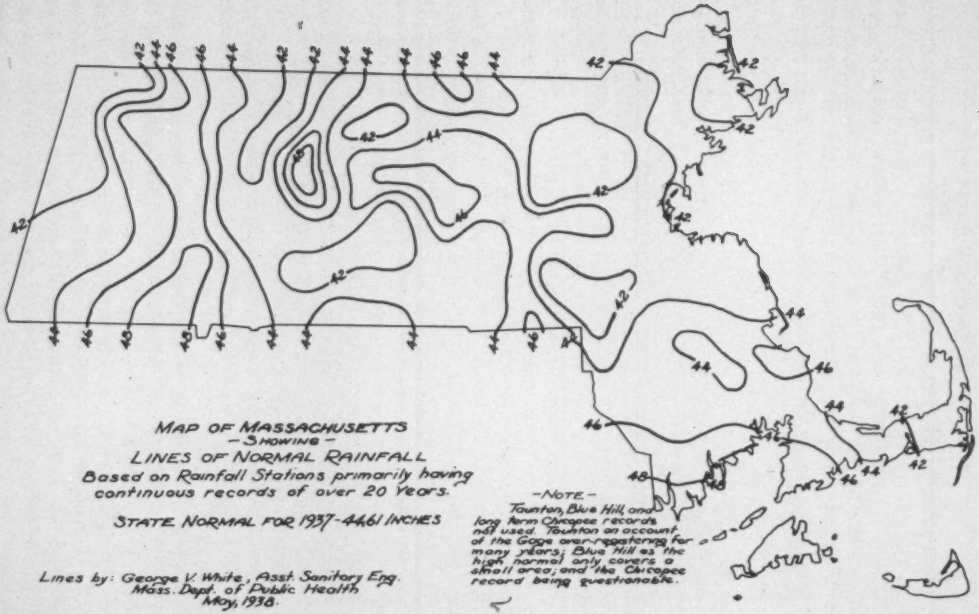

MAP OF MASSACHUSETTS
-SHOWING-
LINES OF NORMAL RAINFALL
Based on Rainfall Stations primarily having continuous records of over 20 Years.
STATE NORMAL FOR 1937-44.61 INCHES
Lines by: George V. White, Asst. Sanitary Eng. Mass. Dept. of Public Health May, 1938.
-NOTE-
Taunton, Blue Hill and long term Chicopee records not used. Taunton on account of the Gage over-reporting for many years; Blue Hill as the high normal only covers a small area, and the Chicopee record being questionable.

FIGURE 5

DIAGRAM SHOWING
PROGRESSIVE AVERAGE RAINFALL IN EASTERN MASSACHUSETTS
1749 - 1937

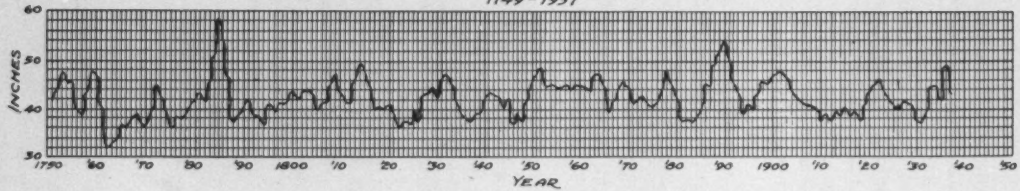
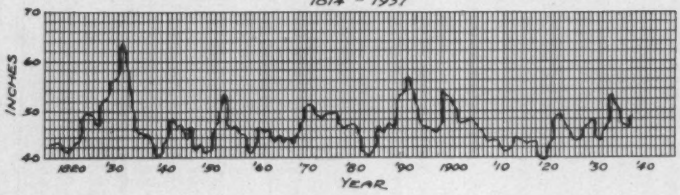


DIAGRAM SHOWING
PROGRESSIVE AVERAGE RAINFALL AT NEW BEDFORD
1814 - 1937



-NOTE-

The progressive average is made by plotting the successive averages of the rainfall for three year periods upon the ordinate representing the last year of the period.

Originally published in a paper on Rainfall in New England by X.H. Goodnough - New England Water Works Journal, Vol. XXIX, Sept, 1915.
The extensions through 1937 are by George V. White, Asst. Sanitary Engineer, Mass. Dept. of Public Health

FIGURE 6

by Mr. Goodnough a diagram was included showing the three year progressive average rainfall from 1750 to 1913. As a matter of interest, this diagram has been brought up to date by Mr. George V. White and is reproduced here as Figure 6. However, one will do well to read the text of Mr. Goodnough's paper in its entirety. A careful examination of Figure 6 will show several periods of low rainfall that become of prime importance in any estimate of safe yield.

Evaporation. Fitzgerald's measurements showed the following monthly evaporation in inches of depth from water surfaces at Chestnut Hill Reservoir:

January	0.96	May	4.46	September	4.12
February	1.05	June	5.54	October	3.16
March	1.70	July	5.98	November	2.25
April	2.97	August	5.50	December	1.51

Total Yearly Evaporation 39.20 inches

The evaporation from undrained swamps is usually computed at 40% and from drained swamps at 30% of that from open water surfaces.

Runoff. Runoff, as the word implies, is a term used to designate that portion of the rainfall which reaches a stream or reservoir not only over the surface of the ground but by underground flow as well. It is the underground contribution which, in a large measure, sustains the dry-weather flow. The total runoff, however, is considerably less than the total rainfall, much of which is lost by evaporation, use by trees and other vegetation, percolation to underground storage or diversion underground outside the limits of the drainage area of the particular stream under consideration. In order to present a general picture of the relation between rainfall and runoff the following figures are taken from records of the yield of Wachusetts Reservoir, a principal source of supply of the Metropolitan Water District located on the South Branch of the Nashua River with its dam at Clinton, Mass.

YIELD OF LAND SURFACE (Average 1908-1937)

RAINFALL (Inches)	LOSSES (Inches)	COLLECTION (Inches)	PER CENT COLLECTED
44.41	20.27	24.14	54.4

YIELD OF WATER SURFACE (Average 1908-1937)

RAINFALL (Inches)	EVAPORATION* (Inches)	COLLECTION (Inches)	PER CENT COLLECTED
44.41	39.20	5.21	11.7

Although the rainfall is fairly well distributed throughout the year

*Fitzgerald Evaporation.

in Massachusetts the variation in amount from year to year and the retention of precipitation in the form of snow during the winter months results in many variations of runoff. Such variations for a single watershed are shown in Figure 7 for the Nashua River.

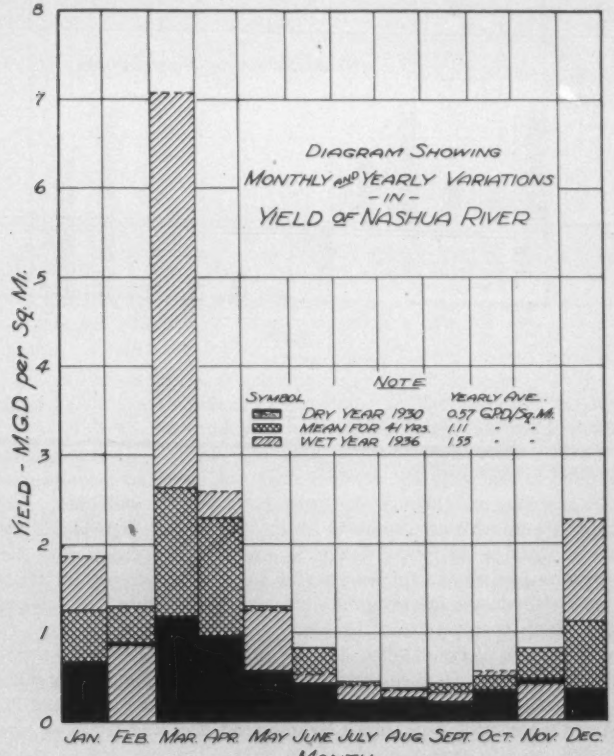


FIGURE 7

Note: The yearly averages are m.g.d. per sq. mile not g.p.d. per sq. mile.

In addition to the variations in runoff occasioned by climatic conditions other variations are introduced by the character of the watershed. Steep watersheds produce rapid runoff, while relatively flat drainage areas may result in sluggish flow. Natural ponds,

meadows and swamps retain the rainfall and delay its entrance into the stream. Such variations are shown in Figure 8 where the yield or

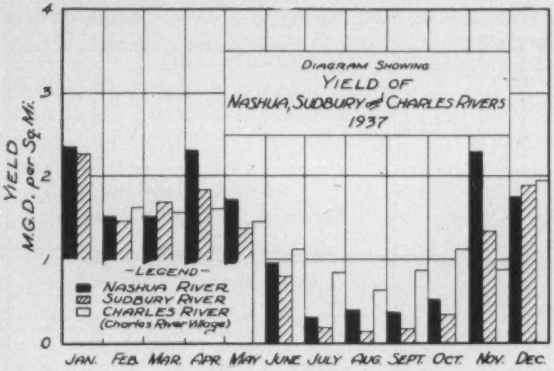


FIGURE 8

runoff for the year 1937 is compared by months for the Wachusett, Sudbury River and Charles River watersheds.

Safe or Dependable Yield. The safe yield of a watershed may be defined as the quantity of water that may be drawn continuously day in and day out through dry periods as well as wet ones. For a running stream with no storage reservoir the safe or dependable yield would be equal to the lowest flow to be expected in a single day. Very few large public water supplies are now taken from streams in Massachusetts without storage reservoirs, the exception being the Lawrence supply which is taken from the Merrimack River.

On certain of the smaller supplies in mountainous territory or in areas where the flow may disappear underground there may be no runoff at all during certain of the drier months. In such cases it is obvious that enough water must be impounded during times of abundant flow to tide over periods of drought. The amount of storage required will depend upon the characteristic variations in the flow of the stream, the degree to which the particular watershed must be developed to meet the needs of the municipality and the economical size of dam and reservoir. It may be less expensive to develop two or more streams than to try to build a reservoir on one large enough to prevent waste overflow from a single reservoir in the very wet years.

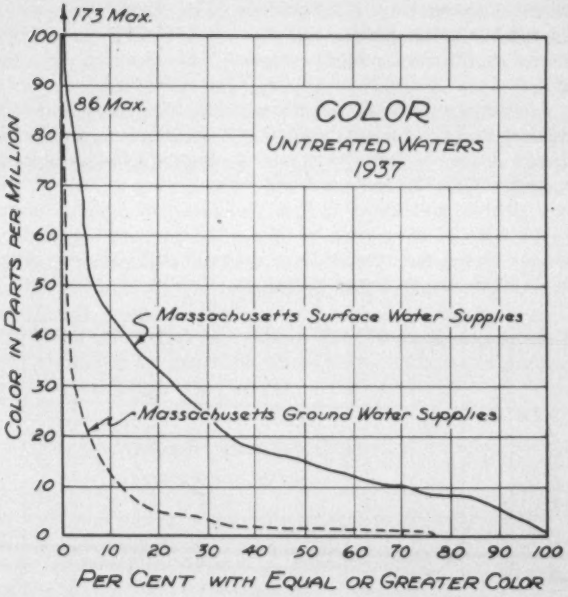


FIGURE 9

Moreover, the development may be carried so far that the loss occasioned by evaporation from the reservoir surface would represent a substantial portion of the flow that might otherwise be expected.

For rough computation it may be expected that in Massachusetts each square mile will on the average deliver to the stream about 1.0 m.g.d. The flow in extremely dry months may drop to 100,000 or 50,000 g.p.d. or fail completely, while in a spring month of a wet year the flow per square mile of watershed may average as high as 7.0 m.g.d. In estimating the required amount of storage certain critical periods are customarily considered. Prior to 1908, the driest extended period of record was that from 1879 to 1884. The long dry period now used for computations of safe yield is that beginning with June 1908 which for large developments must be considered as extending to the autumn of 1915. With the smaller degrees of development, the driest consecutive two years, single year, single month or

day may become the critical periods. The summers of the years 1914 and 1924 were particularly dry and 1910-1911 and 1929-1930 represent short critical periods extending into more than one calendar year.

A detailed presentation of a method of computing yield is given in the report of a committee of this Association on the "Yield of Drainage Areas."[4] A method of computing safe yield based on the percentage of rainfall collected and with varying degrees of storage development is also shown in that report. Other authors have used the application of water losses to the rainfall for computing yield. The late Allen Hazen recommended and used a method of computing safe yield based on the theory of probability.

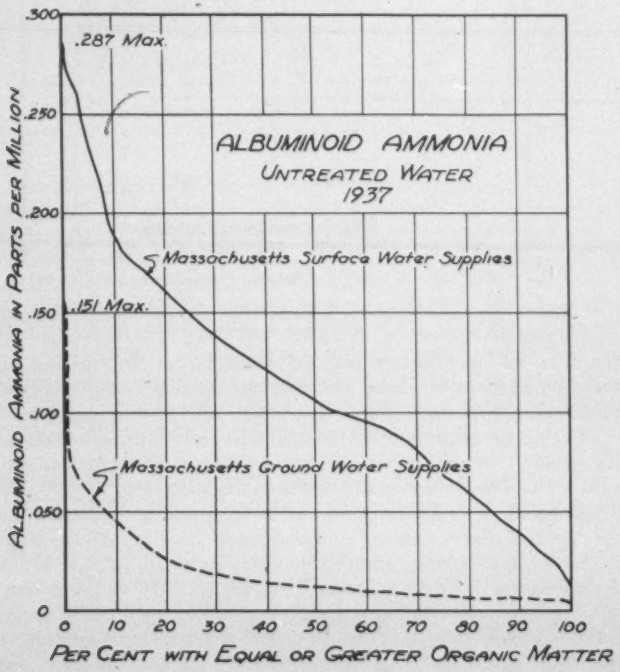


FIGURE 10

[4]This Journal 28 (1914), 397.

The needs of the immediate future may not necessarily determine the degree of development, and plans for the more distant future may control. In the case of Wachusett Reservoir the storage developed was 550 m.g. per square mile looking to the time when the Ware River would be diverted into it and for a time be considered as a part of its tributary area. Then too it may be good engineering judgment to develop sufficient storage so that it will not be necessary to draw the bottom water or to avoid the necessity of exposing a disproportionately large area of reservoir bottom. In such cases the bottom storage becomes a prism of water to support the available storage above and represents an emergency reserve. In many instances, however, the character of the topography and available dam sites will become the governing factors.

A safe yield of from 400,000 to 600,000 g.p.d. per square mile may be developed by providing about 50 to 100 m.g. of storage for each square mile of watershed, and with such a development the reser-

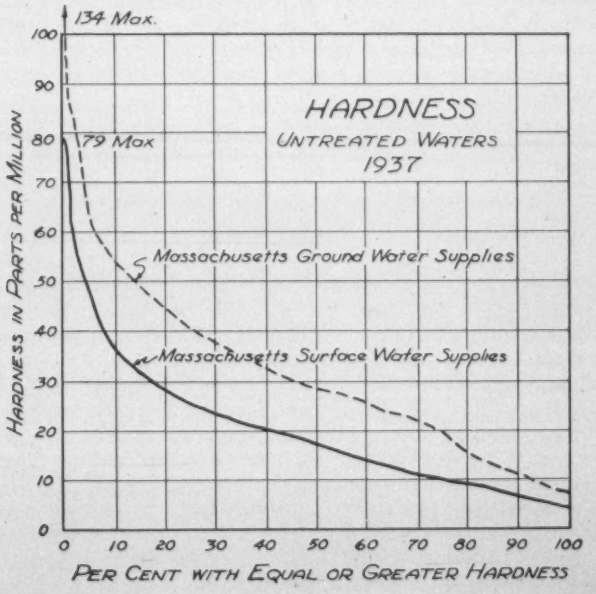


FIGURE 11

voirs may be expected to fill nearly every year. With more extensive development, greater storage must be provided, but for complete development the reservoir might be drawn below high-water mark for a period of 7 to 12 years. Fifty per cent of the surface water supplies in Massachusetts have storage provisions of less than 100 m.g. per square mile of watershed, 15 per cent between 100 and 200, 15 per cent between 200 and 350, with the remaining 20 per cent ranging between 350 to 2,200 m.g. per square mile. Most of those having the larger storage per square mile are natural ponds set aside for water supply purposes and could not have been developed to this degree economically as artificial reservoirs.

Quality of Surface Waters

Physical and Chemical Quality. Surface waters in Massachusetts differ principally as to color, content of organic matter, hardness, and salinity. The latter varies in general inversely as the distance from the ocean. The waters are generally soft, although those originating in limestone regions in the western part of the state are relatively hard. In general, high organic matter both in surface water and ground water supplies may be associated with high color and sometimes high iron content.

Table 4—Range of Chlorides and Hardness in Massachusetts Surface Water Supplies. Average of Analyses for 1937 in P.P.M.

Municipality	Source	Chlorides	Hardness
Wareham			
Onset Fire District	Jonathan Pond (1 mile from ocean)	6.0	7
Maynard	White Pond (22 miles from ocean)	2.5	9
Great Barrington			
Housatonic Water Works Company	Long Pond (120 miles from ocean)	1.3	71*

*Limestone Region.

Table 5—Range of Color, Organic Matter and Iron in Massachusetts Surface Water Supplies. Average of Analyses for 1937 in P.P.M.

Municipality	Source	Color	Albuminoid Ammonia	Iron
Adams	Bassett Brook Reservoir	5	0.061	0.09
New Bedford	Great Quittacas Pond	45	0.151	0.13
Athol	Thousand Acre Meadow Brook Reservoir	173	0.270	0.28

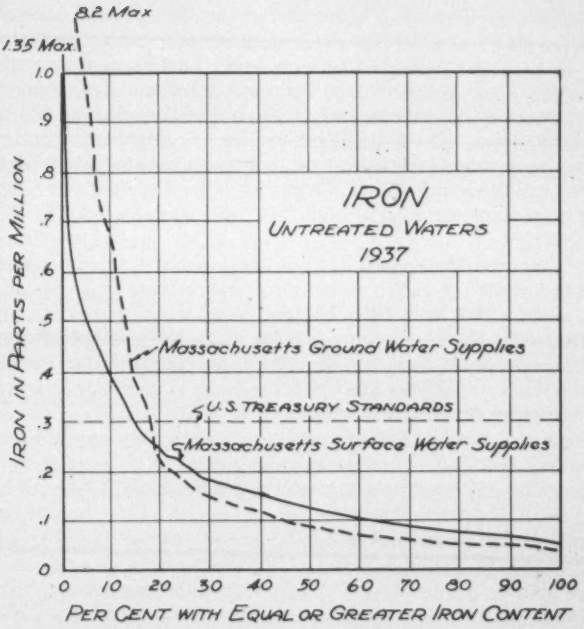


FIGURE 12

Massachusetts surface water supplies are seldom troublesome because of turbidity, although the only large river at present in use for a public water supply, the Merrimack, may become very turbid in unusual flood periods. Certain of the small mountain reservoirs, such as the Glen Brook reservoirs of the Greenfield supply, and the Black Brook Reservoir of the Russell supply, may not have sufficient storage to permit adequate sedimentation of silt, leaf mold and other suspended matter brought into them during freshets. The surface waters for the most part do not have high hydrogen-ion concentrations. Only three otherwise untreated surface water supplies in Massachusetts, those of the towns of Falmouth, Manchester and Winchester, are treated to increase the pH value. There is shown in the following diagram a summary of the pH determinations for Massachusetts public water supplies.

Bacterial Quality. A comparison of the bacterial quality of water supplies may best be made by using the standard adopted by the U. S. Treasury Department for water supplies used on common carriers. These standards are becoming more and more commonly accepted as a general measure of the bacterial quality of all public water supplies. These standards require in general that not more than 10 per cent of the 10-c.c. portions examined shall show bacteria of the coli-aerogenes group. Certain other provisions which relate to particular samples may be found in "Standard Methods of Water Analysis".

While the Merrimack River is the only polluted stream used in Massachusetts for public water supply purposes and the only supply for which filters have been installed with bacterial removal as the prime factor, there has been a growing appreciation of the advantages of treatment as a protection against chance pollution. In recognition of the futility of relying upon purification by storage alone, especially if the period of storage is insufficient or if the theoretical period of storage may not be realized because of short circuiting, chlorinators have been installed in connection with certain of the supplies of 100 municipalities, including those of the Metropolitan Water District. Additional protection has also been incidental to the installation of filters for the removal of color and organic matter and microscopic organisms. To permit a better understanding of the degree of bacterial pollution to be expected under different circumstances, Table 6 is presented.

TABLE 6—DENSITY OF COLI-AEROGENES BACTERIA IN WATER OF VARYING DEGREES OF POLLUTION

	COLI-AEROGENES BACTERIA PER 100 CUBIC CENTIMETERS (Most Probable Number)
Raw Sewage—Boston	24,000,000.
Merrimack River at Lawrence (Bacteria results for 1937)	24,000.
U. S. Treasury Standards Allowable for drinking water on common carriers.	1.05
Wachusett Reservoir at Outlet (Bacterial results for 1937)	0.0

Microscopic Organisms. Microscopic organisms, forms of life much more highly organized than the bacteria, yet so small that a

microscope is needed to see most of them, are the frequent cause of disagreeable tastes and odors in surface water supplies. Examinations of the annual reports of municipal water departments and of the Massachusetts State Board of Health and its successors show many references to complaints of objectionable tastes and odors, especially of cucumber and fishy odors. The organism known as *Uroglena*, or *Uroglenopsis*, is frequently mentioned. This organism, together with *Synura*, was responsible for the wide-spread complaints as to the quality of water supplied from Spot Pond by the Metropolitan Water District in 1932 as reported to this Association in a paper by Samuel E. Killam with a brief discussion by Joseph C. Knox.[5]

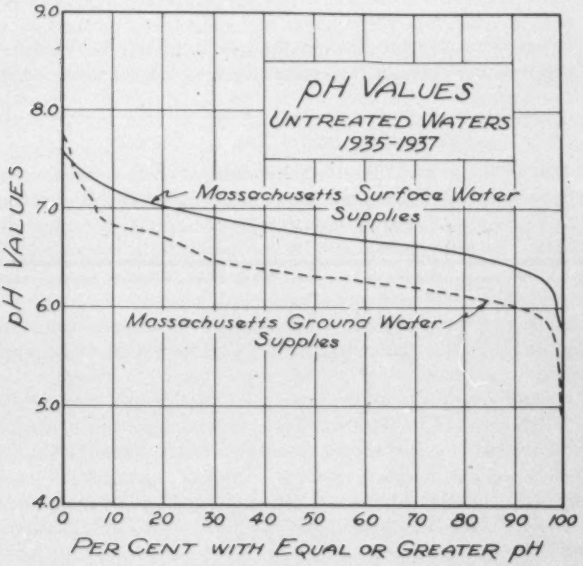


FIGURE 13

Investigations by the State Board of Health from 1903 to 1905, assisted by the U. S. Department of Agriculture, showed the possibility of controlling the growth of such organisms by treating the water of reservoirs and ponds with copper sulphate. Subsequent ex-

[5]This Journal **46** (1932), 241.

periments, especially those by Frank E. Hale in connection with the sources of supply of the city of New York, permit varying the dose according to the type of organisms present. Chlorination is also effective in small reservoirs where a thorough dosing may be accomplished before the free chlorine is lost to the atmosphere. Of all the reservoirs in Massachusetts where the water has become unfit at times because of microscopic organisms, the Ludlow Reservoir of the Springfield water supply has continued to be most notorious. Certain supplies have required treatment with copper sulphate at more or less regular intervals, among them Cape Pond, Rockport; Middleton Pond, Middleton; the Winchester reservoirs; certain reservoirs of the Metropolitan Water District; and the reservoirs of the Lenox supply being notable examples. Experience seems to indicate that many of the smaller reservoirs that are flushed frequently by freshets and the larger deeper ponds and reservoirs have a lesser growth of microscopic organisms.

Water Treatment and Protection

Water Treatment. Public health administration as an idea had its beginning in Massachusetts with the so-called Shattuck report in 1850. This was followed in 1869 by the creation of the State Board of Health and the establishment of its Engineering Division in 1886. The encouraging experiences in Europe with filtered water supplies were reported in this country by James P. Kirkwood who had travelled for information to guide him in his studies for improving the water supply of St. Louis. Dr. William R. Nichols was investigating and experimenting for the Massachusetts State Board of Health.

Certain quotations in the reports of that Board show the early trend of thought. The 1869 report states with regard to water, " . . . Organic impurity we have most to dread . . . " that of 1870, " . . . typhoid is a less frequent disease since the introduction of pure water . . . ", and in 1872, " . . . future health of the crowded cities and towns . . . closely depend upon the preservation of . . . reservoirs of pure water for domestic use".

In the early years notice was taken of the encroachment of the town of Natick upon the waters of Lake Cochituate after 26 years of use as a supply for Boston. Rudimentary filters were constructed on Pegan Brook at its entrance to Lake Cochituate as early as 1864. Works were proposed in 1873 for diverting some of the objectionable refuse from the Mystic Lake supply. Filter galleries were proposed for Lowell and Lawrence on the banks of the

Merrimack River and a filter constructed for Lowell in 1873 according to English practice. The 1876 report of the Board stated that "Systematic filtration as practiced in Europe is not appreciated in this country or we are not yet ready to make the necessary outlay for properly carrying on such a scheme". In 1879 this warning was given following an investigation relative to typhoid fever, "The early introduction of a pure water supply, with adequate sewerage in all large towns in the State, is a matter of prime importance. If the completion of such works should be attended with results similar to those witnessed in many cities of England and Wales, we should be enabled to record a decided diminution in the mortality from typhoid fever within the following ten years, and a consequent gain to the State, which could scarcely be reckoned in terms of pecuniary value". A few years later, in 1884, the Board warned that "It is incumbent upon municipalities of the State to lose no time in taking measures to remedy every source of danger".

With the creation of the Engineering Division in 1886 began the systematic classification and study of public water supplies in Massachusetts. The establishment of the Lawrence Experiment Station and the results of varied experiments on the purification of water and sewage permitted the publication of two special reports in 1890 entitled "Examination of Water Supplies" and "Filtration of Water and Sewage".

A paper read before this Association on October 1, 1931 by Robert Spurr Weston* bears the title "The Development of Water Purification in New England". This paper refers to the experiences in Europe in the early part of the nineteenth century with cholera and typhoid fever. Their relation to public water supply and water treatment is described together with the progress in water treatment in this country. It is probable that the more or less favorable experience with upland surface water supplies and the relatively large number of ground water supplies has prevented the general adoption of filtration in Massachusetts.

Studies of the prevalence of typhoid fever and its relation to water supplies led the State Board of Health through its Committee on Water Supply and Sewerage to write to the Mayor of Lawrence on January 10, 1891, as follows:

"The State Board of Health has been engaged many weeks in seeking the cause of the prevalence of typhoid fever in Lawrence; and, although the investigation is not completed, the facts obtained point so strongly to the city water as being one

*This Journal 45 (1931), 315.

important cause that the Board feels warranted in warning the citizens not to use it for drinking until after it has been boiled at least fifteen minutes; and that when boiled it should not be cooled by putting into it ice obtained from the river this winter. This precaution should be continued as long as typhoid fever prevails in Lowell."

In a letter to the Mayor of Lawrence, dated January 30, 1891, the question of typhoid fever and water supply was discussed at length.

Lowell abandoned its surface water supply in favor of tubular wells, and Lawrence adopted filtration of all water supplied from the river. It is said that it required the repeated pleadings of Mr. Mills, which at one moment brought him literally to tears, to convince the city authorities of Lawrence that filtration was necessary if they were to continue to use the Merrimack River as a source of water supply and avoid repeated epidemics of typhoid fever.

In 1893, after the Lawrence filter had been in use for eight months, Mr. Mills stated in his report on the results of its operation that,—

"The study of this problem and its solution have established with more of certainty than ever before three important points in sanitary science:—

1. The insufficiency of the self-purification of streams.
2. The ready conveyance of typhoid fever down a stream by sewage-polluted drinking water.
3. The practicability of protecting a community against an infected drinking water supply by natural sand filtration."

An epidemic of typhoid fever in Newburyport caused a newly formed water company in 1892 to install an improvised filter for treatment of the water of the Merrimack River, but soon thereafter the river supply was abandoned and a ground water supply established.

For thirty years between 1870 and 1900 the advantages of filtration were secured by the introduction of filter galleries often under the mistaken assumption that the water of the stream near which they were located would supply large quantities of water filtered through the intervening soil. Such filter galleries have since been recognized and classified as ground water works supplied for the most part by water from the upland on its way underground to seek its lowest possible level. Filtration works were in some instances established to reduce the pollution entering reservoirs from thickly settled areas in the form of surface drainage.

Certain sketches depicting the progress of filtration in Massachusetts and illustrative of the ingenuity accompanying its gradual acceptance are shown in Figures 14 to 22.

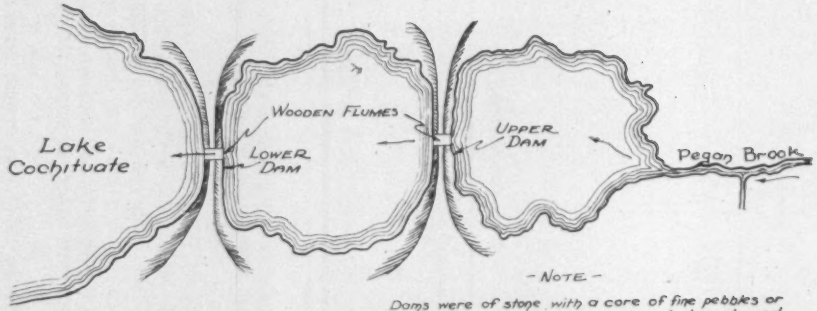

Lake Cochituate
Wooden Flumes
Lower Dam
Upper Dam
Pegan Brook
- NOTE -
Dams were of stone with a core of fine pebbles or screened gravel which could be replaced when clogged without disturbing main portion of dam.
Lower dam was built in 1863 and repaired in 1867.
Upper dam was built in 1870
5'
Section Through Dam
Boston Water Supply - Lake Cochituate
FILTER DAMS ON PEGAN BROOK
1863 - 1867 - 1870

FIGURE 14

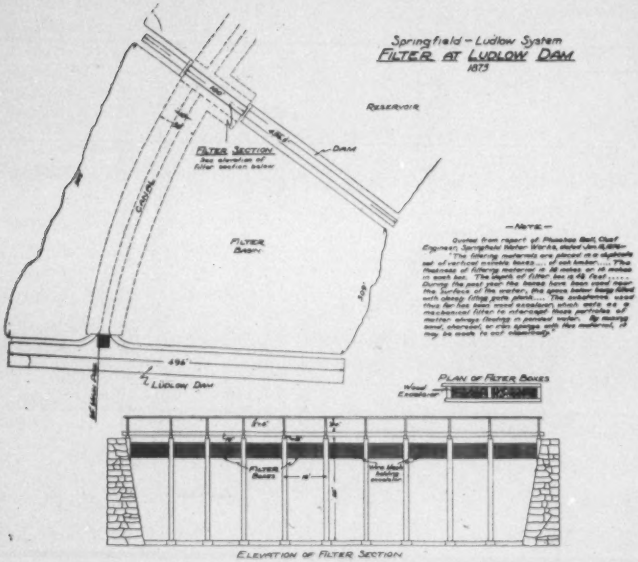


FIGURE 15

The introduction of filter galleries and similar works, slow sand filters, rapid sand filters and chlorination for the treatment of surface waters in Massachusetts is shown in Tables 7 to 9.

Protection of Catchment Areas. With the passage of Chapter 510 of the Acts of 1897 by the Massachusetts General Court, the importance of a clean watershed was reaffirmed and by that important piece of legislation the State Board of Health was empowered to adopt rules and regulations for preventing the pollution and securing the sanitary protection of inland waters used as sources of public water supply. After amendment by Chapter 467 or the Acts of 1907 authorizing the Board to delegate the granting of certain permits to local authorities, this legislation now appears in Section 160, Chapter 111 of the General Laws (Tercentenary Edition).

The first set of rules and regulations under this legislation were adopted for the sources of water supply of the city of Cambridge on August 3, 1899, although similar rules and regulations had been adopted under separate legislation on June 20, 1899 for the benefit

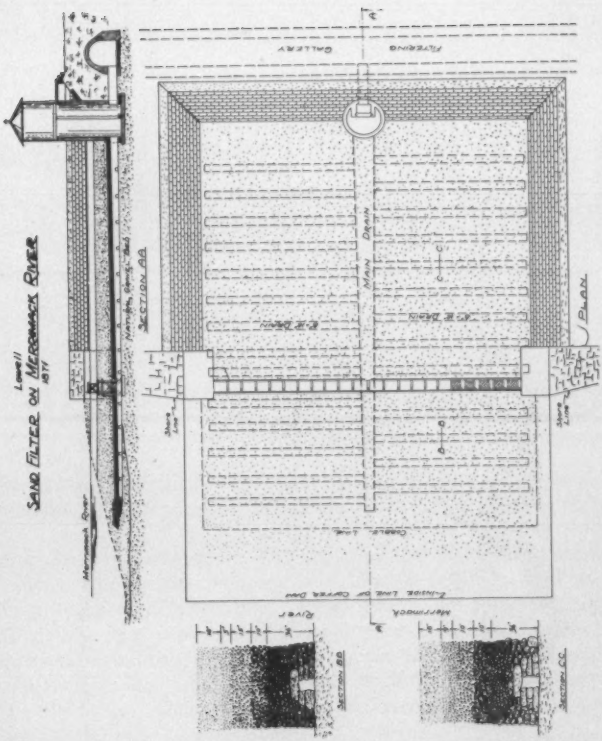

SAND FILTER ON MERRIMACK RIVER
Lowell
1877
Merrimack River
Natural Gravel Bed
SECTION BB
FILTERING GALLERY
MAIN DRAIN
C.I. C.
E.F. MAIN
A.F. MAIN
BRAN.
Stone Line
Stone Line
Outside Line of Coffer Dam
MERRIMACK RIVER
SECTION BB
SECTION CC

FIGURE 16

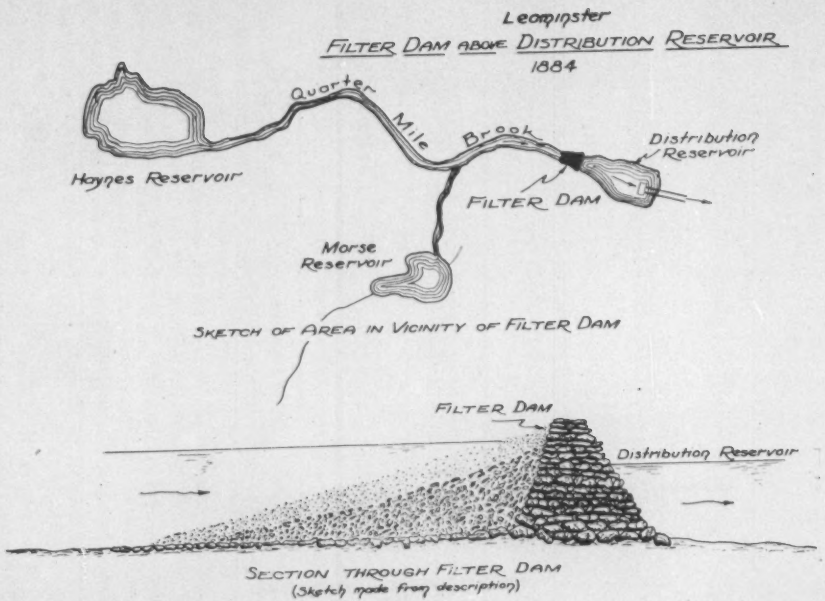

Leominster
FILTER DAM ABOVE DISTRIBUTION RESERVOIR
1884
Quarter Mile Brook
Haynes Reservoir
Distribution Reservoir
FILTER DAM
Morse Reservoir
SKETCH OF AREA IN VICINITY OF FILTER DAM
FILTER DAM
Distribution Reservoir
SECTION THROUGH FILTER DAM
(Sketch made from description)

FIGURE 17

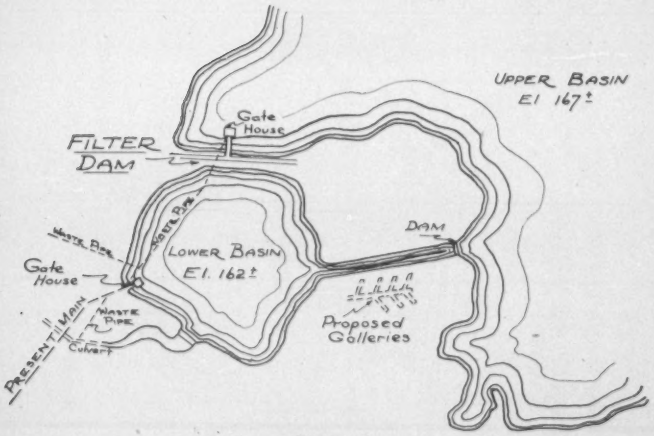


FIGURE 18

of the newly established Metropolitan Water District. Such rules and regulations have been adopted for the surface water supplies of 83% of the municipalities in Massachusetts served in whole or in part from surface water sources. The fact that they have stood the tests of court action speaks well for the common sense as well as the sanitary training of those who framed them. The rules and regulations adopted from time to time at the request of local authorities have continued essentially in the same form as the first to be adopted. For the convenience of those who may wish to become familiar with their provisions a skeleton copy of a set recently adopted is quoted herein.

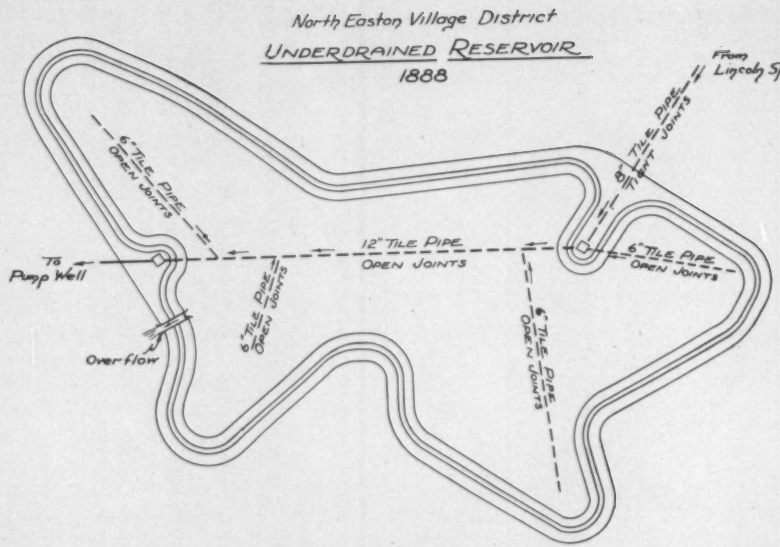
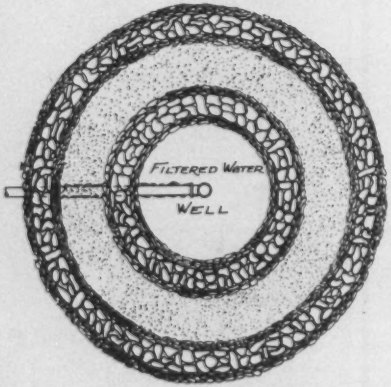

North Easton Village District
UNDERDRAINED RESERVOIR
1888
From Lincoln Spring
8" Tile Pipe Open Joints
6" Tile Pipe Open Joints
12" Tile Pipe Open Joints
6" Tile Pipe Open Joints
To Pump Well
6" Tile Pipe Open Joints
6" Tile Pipe Open Joints
Over flow

FIGURE 19

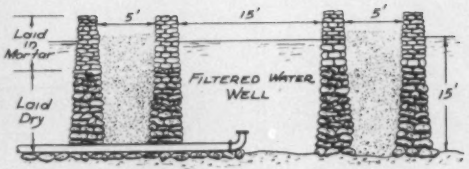
NORTH BROOKFIELD

CIRCULAR FILTER DAM IN DOANE POND

1893



PLAN



SECTION

-NOTE-

Coarse filter material found necessary to furnish sufficient water for the pumps. Coarse gravel used in 1922

Filter is backwashed by raising level of water in well above level of water in the surrounding reservoir.

FIGURE 20

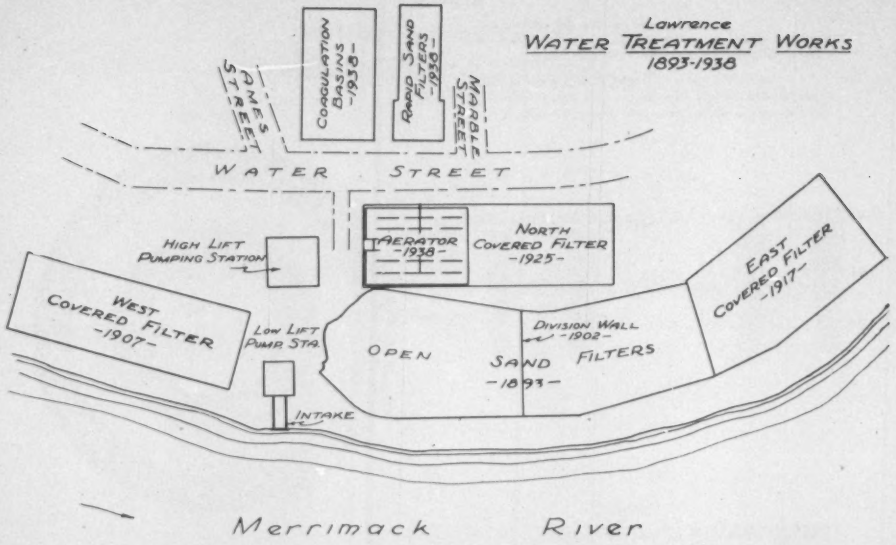

Lawrence
WATER TREATMENT WORKS
1893-1938
COAGULATION BASINS -1938-
RAPID SAND FILTERS -1938-
AMES STREET
MARBLE STREET
WATER STREET
AERATOR -1938-
NORTH COVERED FILTER -1925-
EAST COVERED FILTER -1917-
HIGH LIFT PUMPING STATION
WEST COVERED FILTER -1907-
LOW LIFT PUMP STA.
OPEN SAND FILTERS -1893-
DIVISION WALL -1902-
INTAKE
Merrimack River

FIGURE 21

Lawrence

TREATMENT WORKS FOR MERRIMACK RIVER WATER

1893-1938

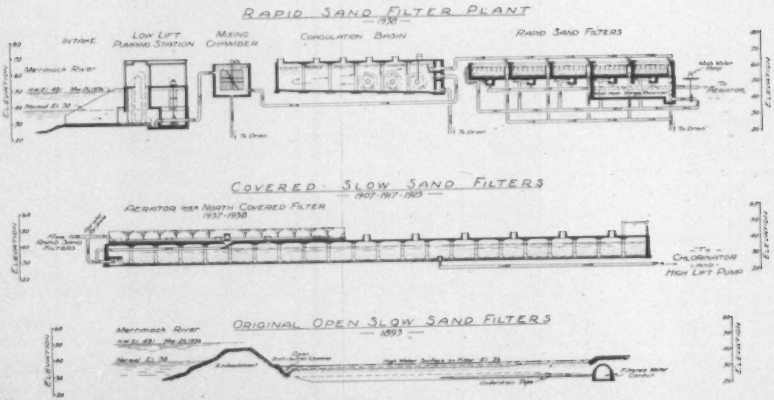


FIGURE 22

TABLE 7.—FILTER BASINS, GALLERIES, DAMS, CRIBS AND UNDERDRAINED RESERVOIRS IN MASSACHUSETTS SURFACE WATER SUPPLIES.

Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900	1901 to 1910	1911 to 1920	1921 to 1930	Since 1930
			Open Filter Basins				
	1876 Newton						
	1876 Taunton						
	1873 Waltham	1885 Amesbury	Amesbury	Holliston			
			Filter Galleries or Collecting Drains				
		1885 Arlington					
		1882 Attleboro					
		1887 Braintree					
	1876 Arlington	1883 Brookline					
	1880 Brockton	1887 Easton					
	1875 Brookline	1885 Framingham	1891 Kingston				
	1879 Brookline	1888 Kingston	1891 Leicester				

	1876 Cambridge	1884 Lexington	1892 Lexington				
	1875 Lawrence	1890 Newton	1899 Maynard	1902 Cohasset			
	1872 Lowell	1889 Northbridge	1892 Newton	1903 Hingham			
	1876 Taunton	1890 Oak Bluffs	1894 Newton	1903 Needham			
	1879 Uxbridge	1887 Tisbury	1891 Reading	1909 Newton	1911 Brookline		
1870 Northbridge	1878 Wayland	1885 Watertown	1893 Stoughton	1909 Oak Bluffs	1912 Marblehead		
1860 Springfield	1872 W. Brookfield	1884 Wellesley	1891 Watertown	1903 Shirley	1911 South Hadley Fire Dis. No. 1	1929 Chatham	
1858 W. Brookfield	1873 Woburn	1883 Whitman	1896 Winchendon	1901 Webster	1925 E. Brookfield	1934 Gr. Barrington	

Filter Dams, Cribs or Underdrained Reservoirs

		Filter Crib Hingham	Underdrained Reservoir Holyoke
Filter Dams Boston 1867 Pegan Brook 1870 Pegan Brook	Underdrained Reservoirs 1880 Avon Easton	Filter Dams 1884 Leominster Taunton 1887 Westborough	Filter Crib 1893 Orange Filter Dam 1893 No. Brookfield

TABLE 8.—SLOW AND RAPID SAND FILTERS IN MASSACHUSETTS SURFACE WATER SUPPLIES.

Prior to 1870	1871 to 1880	1881 to 1890	1891 to 1900	1901 to 1910	1911 to 1920	1921 to 1930	Since 1930
				Slow Sand Filters			
				1902 Lawrence Open filter Divided			
				1907 Lawrence Covered filter Added			
				1902 Milford Open Filter & 2 Covered Filters			
				1903-1910 Newburyport Open filters added.			
			1893 Lawrence Open	1909 Newburyport Covered filter	1913 Athol Open	1925 Lawrence Covered filter added.	All Covered
			1896-1899 Milford & Hopedale Open	1906 Springfield (Ludlow) Open	1917 Lawrence Covered fil- ter added.	1925 Springfield (West Parish) Additions	1935 Greenfield
			1891 Nantucket Open	1909 Springfield (West Parish) Covered	1916 Newburyport Open filter added.	1928 Wakefield Covered	1934 Newburyport
			1892 Newburyport Open	1908 Southbridge Open	1915 Northfield Schools, Inc. Open	1929 West Springfield Covered Additions	1936 Northborough
							1938 Monroe
							1937 Russell
							1931 So. Hadley Fire Dis. No. 2
	1876 Lowell Open	Quincy Open	1893 Stoughton Open	1907-1908 West Springfield Open	1913 Norwood Open		

1887
Athol
(Pressure)

1922
Cambridge
Covered

1924
Scituate
Covered

1935
Weymouth
Covered

1935
Salem &
Beverly
Covered

1936
Randolph &
Holbrook
Covered

1936
Leominster
Covered

1938
Lawrence
Covered

1931
Chicopee
Covered

1932
Cambridge
Addition

1934
Braintree
Covered

1937
Athol
Covered

KINGSBURY.

TABLE 9.—CHLORINATION AND AMMONIATION OF MASSACHUSETTS SURFACE WATER SUPPLIES

Prior to 1910	1911 to 1920	1921 to 1930	Since 1930
			1932 Andover
			1933 Ashburnham
			1935 Clinton
			1937 Dalton (Emergency)
			1934 Danvers & Middleton
			1934 So. Deerfield W. S. District (Seasonal)
			1934 Egremont (Seasonal)
			1932 1937 (A) Fall River
			1935 Franklin* (Emergency)
			1934 Gardner
			1938 Great Barrington Fire District
			1935 Gloucester
			1933 Haverhill
			1937 Hatfield (Emergency)
			1934 Hingham*
			1933 Holden
			1933 Ipswich
			1933 Lenox* (Seasonal)
			1937 (A) Leominster*
			1933 Leominster

TABLE 9.—CHLORINATION AND AMMONIATION OF MASSACHUSETTS SURFACE WATER SUPPLIES

Prior to 1910	1911 to 1920	1921 to 1930	Since 1930
			1935 Lynn
			1934 Maynard
		1927 (A) Abington & Rockland	1931 Milford & Hopedale
		1928 Adams	1935 Monson
		1928 Amherst	1932 Newburyport (Seasonal)
		1926 Braintree	1933 No. Adams*
		1923 Cambridge	1937 No. Brookfield
		1926 Chicopee	1932-1937 Northampton
		1929 Lee	1934 Northborough
		1928 Marlborough	1933 Northfield Schools, Inc.
		1930 1931 1937 (A) Metropolitan	1933 Palmer Fire Dis. No. 1
		1925 Peabody	1934 Pittsfield
		1924 Rockport	1934 (A) Randolph & Holbrook
		1930 Southborough	1931 Rutland
		1927 So. Hadley Fire Dis. No. 1	1935 (A) Salem & Beverly
		1928 Springfield* (Emergency)	1931 Scituate*
	1919 Framingham	1923 Stockbridge	1937 Southbridge
	1920 Greenfield	1927 Westfield	1936 Stoughton
	1918 Lawrence	1927 W. Springfield	1937 Westfield
	1920 No. Andover	1923 Woburn* (Emergency)	1932 Williamstown* (Seasonal)
	1918 Wakefield		1935 Winchester

NOTE: (A) Ammoniation
* Certain of the sources only

COMMONWEALTH OF MASSACHUSETTS

Department of Public Health

Rules and Regulations

for the

Purpose of Preventing the Pollution and Securing the Sanitary Protection of the Waters of ..... Lake and ..... Reservoir and their Tributaries, used by ..... as Sources of Water Supply.

The Department of Public Health, acting under the authority of section 160 of chapter 111 of the General Laws, and every other act thereto enabling, hereby makes the following rules and regulations for the purpose of preventing the pollution and securing the sanitary protection of the waters of ..... Lake and ..... Reservoir and their tributaries, used by .... as sources of water supply, which shall remain in force until further order, and which may be hereafter from time to time amended or added to by the Department of Public Health.

1. No cesspool, privy, or other place for the reception, deposit, or storage, of human excrement, and no urinal or water-closet not discharging into a sewer, shall be located, constructed or maintained, within fifty feet of high-water mark of ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of .... and used by ..... as sources of water supply, or within fifty feet of high-water mark of any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into either said lake or reservoir.

2. No human excrement shall be deposited or discharged in or into ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and city of ..... and used by ..... as sources of water supply, or into any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into either said lake or reservoir; and no human excrement shall be kept in, or deposited or discharged in or into, any cesspool, privy, or other receptacle, situated within two hundred and fifty feet of high-water mark of either said lake or reservoir, or within two hundred and fifty feet of high-water mark of any open waters, the water of which flows directly or ultimately into either said lake or reservoir, unless such cesspool, privy, or other receptacle, is so constructed that no portion of its contents can escape or be washed into either of said waters.

3. No human excrement, or compost containing human excrement, or contents of any privy or cesspool or sewer, or other receptacle for the reception or storage of human excrement, shall be deposited or discharged upon or into the ground at any place from which any such excrement, compost, or contents, or particles thereof, may flow or be washed or carried into ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by .... as sources of water supply, or into any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into either said lake or reservoir.

4. No house slops, sink waste, water which has been used for washing or cooking, or other polluted water, shall be discharged into ..... Lake

or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply, or into any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into said lake or reservoir; and no house slops, sink waste, water which has been used for washing or cooking, or other polluted water, shall be discharged into the ground within fifty feet, or upon the ground within two hundred and fifty feet, of high-water mark of said lake or reservoir, or into the ground within fifty feet, or upon the ground within two hundred and fifty feet, of high-water mark of any open waters flowing as aforesaid into either said lake or reservoir.

5. No garbage, manure, or putrescible matter whatsoever, shall be put into ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply, or into any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into either said lake or reservoir; and no garbage, manure, or putrescible matter whatsoever, shall, except in the cultivation and use of the soil in the ordinary methods of agriculture, be put upon the ground within two hundred and fifty feet of high-water mark of either said lake or reservoir, or within two hundred and fifty feet of high-water mark of any open waters flowing as aforesaid into either said lake or reservoir.

6. No stable, pig-sty, hen-house, barn-yard, hog-yard, hitching or standing place for horses, cattle or other animals, or other place where animal manure is deposited or accumulates, shall be located, constructed, or maintained, any part of which is within fifty feet of high-water mark of ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply, or within fifty feet of high-water mark of any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into said lake or reservoir; and no stable or other place, as above enumerated, shall be located, constructed, or maintained, within two hundred and fifty feet of high-water mark of either said lake or reservoir, or within two hundred and fifty feet of high-water mark of any open waters flowing as aforesaid into either said lake or reservoir, unless suitable and adequate provision is made to prevent any manure or other polluting matter from flowing or being washed into either said lake or reservoir.

7. No interment shall, except by permission in writing by the Board of Water Commissioners of ....., be made in any cemetery or other place of burial, within fifty feet of high-water mark of ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ....., and used by ..... as sources of water supply, or within fifty feet of high-water mark of any reservoir, lake, pond, stream, ditch, water course or other open waters, the water of which flows directly or ultimately into said lake or reservoir.

8. No lands, which were not under the control of cemetery authorities and used for cemetery purposes on ..... from which the natural drainage flows into ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply, or

into any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into either said lake or reservoir, shall be taken or used for cemetery purposes until a plan and description of the lands which it is proposed to use for such purposes, sufficient for their identification, shall be presented to the Department of Public Health, and until such taking or use shall be approved in writing by the Department of Public Health.

9. No manufacturing refuse, or waste product, or polluting liquid, or other substance of a nature poisonous or injurious either to human beings or animals, or other putrescible organic matter whatsoever, shall be discharged directly into, or at any place from which it may flow or be washed or carried into, ... Lake or ..... Reservoir, so called, said lake and reservoir being ..... as sources of water supply, or into any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into either said lake or reservoir.

10. No system of sewers or other works for the collection, conveyance, disposal, or purification, of domestic or manufacturing sewage or drainage, or any other putrescible organic matter whatsoever, shall, except in accordance with plans first approved in writing by the Department of Public Health, be constructed or maintained at any place within the watershed of ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply. No private or separate sewer shall be constructed or maintained having an outlet upon or in the ground within two hundred and fifty feet of high-water mark of any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately int either said lake or reservoir.

11. No public or private hospital, or other place intended for the reception or treatment of persons afflicted with a contagious or infectious disease, shall, until the location and construction thereof have been approved in writing by the Department of Public Health, be located or constructed at any place within the watershed of ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply. No public or private hospital, or other place intended for the reception or treatment of persons afflicted with a contagious or infectious disease, shall be maintained at any place within such watersheds, unless all the provisions required by the Department of Public Health for the purification or disposal of sewage, drainage, or other polluting or organic matter, which may be discharged therefrom, have been complied with, and unless all orders issued from time to time by the Department of Public Health in relation to the purification and disposal of sewage, drainage, and other polluting or organic matter, which may be discharged therefrom, are fully complied with.

12. No tannery, currying shop, or other establishment or place where the skin, wool, hair, or fur, of any animal is treated, shall, until the location and construction thereof have been approved in writing by the Department of Public Health, be located or constructed at any place within the watershed of .... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply. No tannery, currying shop, or other establishment or place where the skin, wool, hair, or fur, of any

animal is treated, shall be maintained at any place within such watersheds, unless all the provisions required by the Department of Public Health for the purification or disposal of sewage, drainage, or other polluting or organic matter, which may be discharged therefrom, have been complied with, and unless all orders issued from time to time by the Department of Public Health in relation to the purification and disposal of sewage, drainage, and other polluting or organic matter, which may be discharged therefrom, are fully complied with.

13. No slaughterhouse or other building for carrying on the business of slaughtering cattle, sheep, or other animals, and no melting or rendering establishment, shall, until the location and construction thereof have been approved in writing by the Department of Public Health, be located or constructed at any place within the watershed of ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply. No slaughterhouse or other building for carrying on the business of slaughtering cattle, sheep, or other animals, and no melting or rendering establishment, shall be maintained at any place within such watersheds, unless all the provisions required by the Department of Public Health for the purification or disposal of sewage, drainage, or other polluting or organic matter, which may be discharged therefrom, have been complied with, and unless all orders issued from time to time by the Department of Public Health in relation to the purification and disposal of sewage, drainage, and other polluting or organic matter, which may be discharged therefrom, are fully complied with.

14. No person shall wade or bathe in, and no person shall, unless permitted by a special regulation or by a written permit of the Board of Water Commissioners of ..... fish in, or send, drive, or put, any bird, fowl or animal into ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply; and no person shall wade or bathe in, and no person shall, except by a written permit of the Board of Water Commissioners of ..... fish in, or send, drive, or put, any bird, fowl, or animal into any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into said lake or reservoir. No person other than a member of said Board, its officers, agents, or employees, or public officer whose duties may so require, shall, unless so permitted by regulation or permit of said Board, enter or go, in any boat, skiff, raft, or other contrivance, on or upon the water of said lake or reservoir, or on or upon the water of any reservoir, lake, pond, stream, ditch, water course, or other open waters, the water of which flows directly or ultimately into said lake or reservoir, nor shall enter or go upon, or send, drive, or put, any bird, fowl, or animal, upon the ice of either of said waters.

15. No person shall enter upon ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply, for the purpose of cutting or taking ice, or cut or take ice from either said lake or reservoir, without a written permit signed by the Board of Water Commissioners of ....., stating the time and place for which such permission is given.

The granting and withholding of permits required by rules 7, 14 and 15 are

hereby delegated by the Department of Public Health to said Board of Water Commissioners.

16. All reports which may be made to any board of health, or to any health officer of any town, of cases of contagious or infectious diseases occurring within the watershed of ..... Lake or ..... Reservoir, so called, said lake and reservoir being in the town of ..... and the city of ..... and used by ..... as sources of water supply, shall be open to the inspection at all reasonable times of the Board of Water Commissioners of ....., its officers or agents.

By order of the Department of Public Health,

Commissioner of Public Health.

The enforcement of these rules and regulations is provided for under Section 164 of Chapter 111 of the General Laws (Tercentenary Edition) which reads as follows:

"Section 164. The supreme judicial or superior court, upon the application of the department or of any party interested, may enforce the orders, rules and regulations of said department, and restrain the use or occupation of the premises or such portion thereof as said department may specify on which the material is deposited or kept, or such other cause of pollution exists, until the orders, rules and regulations of the department have been complied with."

The General Court of 1938 enacted Chapter 293 which is of interest in the enforcement of such rules and regulations, providing as it does for the extra-territorial jurisdiction of police officers employed by a city or town in their enforcement. This act reads as follows:

[CHAP. 293]

AN ACT TO EXTEND THE TERRITORIAL JURISDICTION OF CERTAIN POLICE OFFICERS EMPLOYED TO PROTECT PUBLIC SOURCES OF WATER SUPPLY FROM POLLUTION.

Whereas, The deferred operation of this act would tend to defeat its purpose, therefore it is hereby declared to be an emergency law, necessary for the immediate preservation of the public convenience.

Be it enacted, etc., as follows:

Chapter one hundred and eleven of the General Laws is hereby amended by inserting after section one hundred and seventy-three, as appearing in the Tercentenary Edition, the following new section:—*Section 173A.* Police employed by the water board or board of water commissioners of a city, town or water district, a public institution or water company, and duly appointed in one of the cities or towns within an area from which water is being supplied under the direction of such board, institution or company, or over which such board, institution or company has control, or where such water is furnished by such city, town, district, institution or company shall within and throughout any or all of such areas have all the powers and duties of police officers of cities and towns.

Approved May 10, 1938.

TABLE 10—MASSACHUSETTS CITIES, TOWNS, FIRE AND WATER DISTRICTS, AND WATER COMPANIES, FOR WHICH RULES AND REGULATIONS HAVE BEEN ADOPTED BY THE DEPARTMENT OF PUBLIC HEALTH

Abington and Rockland	1927	Leicester (Cherry Valley and Rochdale Water District)	1914
Adams (Fire District)	1921	Lenox (Water Company)	1933
Amherst (Water Company)	1931	Leominster	1919, 1927*
Andover	1908	Lincoln and Concord	1903
Ashburnham	1922	Lynn	1907
Ashfield (Water Company)	1923	Manchester	1934
Athol	1934	Marlborough	1901
Attleboro	1926	Maynard	1907
Braintree	1913, 1926*	Medfield (State Hospital)	1922**
Brockton	1905, 1934*	Metropolitan Water District	1925
Cambridge	1899	Milford (Water Company)	1924
Cheshire (Water Company)	1933	Montague (Turners Falls Fire District)	1908, 1936*
Chester (Fire District)	1914	New Bedford	1932
Chicopee	1906	Newburyport	1921
Clinton	1935	Norfolk (State Hospital)	1926
Cohasset (Water Company)	1923	Northampton	1904
Colrain (Fire District)	1932, 1934*	North Andover	1912
Concord	1910	Northborough	1905, 1934*
Dalton (Fire District)	1919	North Brookfield	1935
Danvers and Middleton	1920	Norwood	1901
Deerfield (So. Deerfield Water Supply District)	1932	Palmer (Fire District No. 1)	1933
Easthampton	1904	Peabody	1922
Egremont (So. Egremont Water Company)	1932	Pittsfield	1903, 1909*
Fall River	1907	Plymouth	1908
Falmouth	1930	Randolph and Holbrook	1926
Fitchburg	1903, 1907, 1918, 1938*	Rockport	1902
Gardner	1910	Russell	1910
Gloucester	1930	Rutland	1914, 1935*
Great Barrington (Housatonic Water Works Company)	1929, 1936*	Salem and Beverly	1901, 1938
Fire District	1938	Scituate	1927
Greenfield	1904	Southbridge (Southbridge Water Supply Company)	1931
Hatfield	1934	South Hadley (Fire District No. 1)	1937
Haverhill	1921	Spencer	1934
Hingham and Hull (Hingham Water Co.)	1912	Springfield	1904, 1910*
Holden	1914, 1935*	Stockbridge (Water Co.)	1910
Holyoke	1908, 1918*	Taunton	1932
Hudson	1929	Wakefield	1904
Huntington Fire District	1938	Westborough	1929
Lakeville (State Sanatorium)	1936	Westfield	1922
Lee (Berkshire Water Company)	1919	West Springfield	1907
		Weymouth	1903, 1935*
		Williamsburg	1914
		Winchester	1909
		Worcester	1926

*Readopted.
**Rescinded 1936.

Every effort should be made to keep pollution from a water supply and every surface water supply should be protected by rules and regulations that the Department of Public Health is prepared to adopt upon request of the local authorities having the supplies in charge. Such rules and regulations when adopted and promulgated in the manner provided by Section 161 of Chapter 111 of the General Laws then have the effect of law and may be enforced under said chapter. A list of municipalities for which rules and regulations have been adopted to date is shown in Table 10.

The watersheds should be adequately patrolled, and frequent detailed inspections should be made of all occupied sites. Signs should be posted in conspicuous places warning the travelling public and others that the waters are used for public water supply and must not be polluted.

Where the enforcement of rules and regulations has proved most difficult, the purchase of land and removal of pollution has been necessary, but the purchase of the entire watershed used for public water supply purposes amounting in Massachusetts to 1140 square miles would appear to be impracticable. The encroachment of population upon public water supplies was noted in Natick as previously stated as early as 1872. Where such advance of municipalities could not be stopped, works have been constructed in some instances for the diversion of sewage and trade waste from the watershed. Such works were proposed in 1873 and later constructed in connection with the Mystic Works of the city of Boston. These were later taken over by the North Metropolitan Sewerage District. Diversion works were constructed in connection with the Lake Cochituate and the Sudbury systems of the Metropolitan Water District. The most extensive diversion scheme was the Holden-Rutland sewer which was constructed for the protection of the Wachusett and Ware River supplies of that district. Where no sewers were available, certain municipalities found it necessary to assume the task and cost of the collection of night soil and to remove it to a point of safe disposal off the watershed.

Fortunately the concentration of population on watersheds of Massachusetts surface water supplies is not great except in a few instances.

Of the watersheds used for water supply purposes 25% are unpopulated, 75% have less than 64 persons to the square mile and 90% have less than 160 per square mile. The water from all but one of the watersheds having more than 160 persons to the square mile is either filtered or chlorinated, or both.

Decrease of Typhoid Fever. The effectiveness of the sanitary control of water supplies is customarily measured by the degree of success in the prevention of water-borne diseases. Fortunately Massachusetts has experienced but little cholera, and typhoid fever has for many years been the yard stick used by sanitarians for this purpose. Table 11 gives the number of deaths from typhoid fever in each of the census years since 1870.

TABLE 11—TYPHOID FEVER IN MASSACHUSETTS, 1870-1937

YEAR	POPULATION	DEATHS FROM TYPHOID FEVER	DEATH RATE PER 100,000 POPULATION
1870	1,457,351	1,333	91.3
1875	1,651,912	1,059	64.1
1880	1,783,085	882	49.5
1885	1,942,141	768	39.4
1890	2,238,943	835	37.4
1895	2,500,183	680	27.2
1900	2,805,346	632	22.5
1905	3,003,680	520	17.3
1910	3,366,416	411	12.2
1915	3,693,310	246	6.6
1920	3,852,356	95	2.4
1925	4,144,205	73	1.8
1930	4,249,614	38	0.9
1935	4,350,910	10	0.2
1937	4,391,428 (Estimated)	13	0.3

Figures 23 and 24 show the geographical distribution of typhoid fever deaths in 1870 and 1937 respectively.

Typhoid fever, however, is beginning to lose its value as an index of the care exercised in the protection of public water supplies, the residual number of cases for several years in Massachusetts having been due entirely to non-water-borne infections. This should by no means lead to a false sense of security because one careless typhoid carrier might pollute a water supply and start a serious epidemic. Eternal vigilance will be necessary to prevent a reoccurrence of explosive epidemics. This and succeeding generations will be justly criticized if they fail to take every precaution made available by sanitary science to prevent the occurrence of water-borne diseases.

Conclusions. The maintenance of sanitary conditions on watersheds will always be of first importance. Charles W. Bunn, Special Master of the Supreme Court of the United States in the Swift River

MAP OF MASSACHUSETTS
SHOWING
DEATHS FROM TYPHOID FEVER
1870—1333

FIGURE 23

MAP OF MASSACHUSETTS
SHOWING
DEATHS FROM TYPHOID FEVER
1937——13

FIGURE 24

case between Connecticut and Massachusetts reported in part as follows:

". . . I think the experts on water and pollution called by the plaintiff and defendant are equally competent and honest in their views. The difference between them seems partly to be a difference between two schools of thought. One looks most favorably on the sinner repentant, the other will have none of him except on compulsion. The one school has the fullest confidence in the processes involved in modern treatment of polluted water and lays less stress on pure source of supply. It suffices them to feel that water will be delivered to the consumer pure. The other school is skeptical about the infallibility of water purification processes and seeks waters that are pure at the source. They advise all cities and municipalities to obtain pure waters wherever practical instead of treating polluted waters. . . ."

The lessons learned in Lowell, Lawrence and Newburyport with typhoid fever caused by the use of the untreated Merrimack River polluted by the sewage of municipalities in Massachusetts and New Hampshire and the experiences of Springfield, Holyoke and Chicopee which caused them to abandon the use of polluted streams in favor of upland water supplies from relatively sparsely populated areas has confirmed the early conclusions of Massachusetts sanitarians. Although the city of Lawrence persists, for financial reasons, in the continued use of the filtered Merrimack River water contrary to the advice of the State health authorities, the municipalities of Massachusetts, with this exception, are firmly convinced of the basic principle that protection of the watershed should come first and that storage and treatment of water thus protected comes as a secondary line of defense. The protection of a watershed may be facilitated by the law extended through rules and regulations to particular watersheds, patrol of watersheds, strict enforcement of such regulations, the diversion of sewage, collection of night soil, filtration of objectionable drainage, and the purchase of offending properties.

Storage of water for considerable periods before use has been found effective in the reduction of bacteria characteristic of pollution. There are so many opportunities for renewed pollution after storage and so many supplies where even the theoretical period of storage is small that additional precautions have been found necessary. In Massachusetts 50% of the surface water supplies have less than one month of theoretical storage at times of freshet flow even when full, 40% have less than one week, and 30% have less than one day's storage under such conditions. When reservoirs have been drawn down or when tributary streams enter them near their outlets, the actual period of storage becomes less than the theoretical. Storage

is of no avail if after storage the water can be polluted at the intake works. In such instances purification by storage may prove to be a fallacy.

Filtration of water supplies in Massachusetts has not been generally adopted as a sanitary safeguard although several plants have been introduced primarily for improving the physical quality of water and have incidentally provided additional bacterial protection. In House Document 1550 of 1922, the Report of the Joint Board consisting of the State Department of Public Health and the Metropolitan District Commission relative to water supply needs and resources of the Commonwealth, the late J. Waldo Smith, Consulting Engineer, stated that "People are growing more and more exacting regarding the quality of water supplied them, and demand, in addition to being safe, that the water should be clean and free at all times from color, odor and turbidity. It seems certain, then, that in the not distant future all surface water supplies must be filtered before delivery to the consumer."

Before passing to the status of other means of treatment it may be appropriate to review the various kinds of filtration. Slow sand filtration has held its own in Massachusetts because of the greater bacterial efficiency claimed for it, equally good results being obtained with this method in the removal of color when used in connection with chemical coagulation in the process sometimes known as modified slow sand filtration. Greater reliability and lower cost of operation are claimed for slow sand filtration over rapid sand filtration. The excellent results to be obtained in the removal of color and turbidity as well as a high degree of bacterial protection afforded by the rapid sand type of filters when properly operated has led to the adoption of this method in many of the newer installations. Moreover, the rapid sand filter may possibly lend itself more readily to the use of materials introduced for the removal of tastes and odors. Considering the more or less simple operation of slow sand filters it seems probable that the smaller municipalities at least will prefer this method when called upon to make a choice as the general adoption of the filtration of surface water supplies is advanced, especially where chemical treatment is unnecessary.

Where filtration has been considered too expensive, or where the physical characteristics of the water have been acceptable, disinfection of water especially from surface sources has made rapid strides in Massachusetts within the last few years. At present 75% of the population supplied from surface water sources, including the resi-

dents of the Metropolitan Water District, are afforded the additional protection of chlorinated water. Ammonia is used in connection with the chlorination of water supplied in the Metropolitan Water District, Fall River and a portion of the supply of Leominster.

The experience of Massachusetts with chlorination may be summarized by the following quotation from the report of Arthur D. Weston, Chief Engineer, Division of Sanitary Engineering, Department of Public Health, in House Document 262, 1938: "The Department of Public Health has also expressed the opinion that, while chlorination of the water is an effective measure in removing bacteria characteristic of pollution, sole reliance on the proper operation of chlorinating apparatus to render polluted water safe for drinking cannot be considered adequate protection of the public health, and other measures should be taken to protect the supplies from pollution."

Vast sums of money have been expended in the construction of public water supplies and in works for their protection. This investment cannot economically be sacrificed to the use of minorities desiring to use them for boating, fishing and other forms of recreation. Public health and water works officials must present a united front against any action that may tend to reduce the safety of our public water supplies.

The water in your drinking glass must be safe.

Acknowledgments. Acknowledgment is again made to Miss Margaret M. Enwright for assistance in preparing this paper for publication as a companion paper to that published in the JOURNAL of this Association on the subject of "Public Ground Water Supplies in Massachusetts." Equal appreciation is accorded the writer's associates in the Engineering Division of the Massachusetts Department of Public Health and others for their helpful criticisms and assistance in the delineation of maps and diagrams.

ALIGNMENT CHARTS FOR THE DESIGN OF PIPE LINES

BY WILLIAM F. COVIL*

[*Received June 1, 1938.*]

The design of pipe lines is essentially a cut and try proposition when it is the designer's objective to obtain the most economical layout consistent with good hydraulic design. In order to facilitate the operations involved in design, which may in some instances necessitate considerable labor, the author has prepared a comprehensive series of alignment charts, in consistent units and with broad ranges, sufficient in scope completely to design the average pipe line from a hydraulic and economical standpoint, whatever the liquid carried.

In doing this the author does not claim that he has contributed anything new in formula, or application, or even that the formulas used are not open to debate as to their validity; but he does claim that when properly used, the charts as constructed will give, at considerable saving in time, results consistent with other procedures now in use.

For proof of the validity of the Reynolds Number as the criterion of similarity between different fluids flowing in the same pipe line reference is made to "Applied Fluid Mechanics" by O'Brien and Hickox.[1] The formula for lost head in a pipe line $h_f = 0.0252f\frac{L}{D^5}Q^2$ is derived from the well-known equation $h_f = f\,\frac{L}{D}\,\frac{V^2}{2g}$.

Use of the Charts. The elements of design that we must know for the solution of normal problems are as follows:

1. Viscosity of liquid flowing in pipe (μ)
2. at a given temperature[2]
3. and density (ρ)
4. Length of straight pipe (L) needed
5. with number of valves and various types of fittings.
6. The difference in elevation to which the liquid must be raised, if it is pumped, or the head which is available for loss in the case of gravity flow (h_f).

The element of design that we must assume is the diameter of

*Assistant Civil Engineer, Metropolitan District Water Supply Commission, Boston, Mass.

[1]McGraw-Hill Book Co., New York, 1937.

[2]The viscosity of liquids is known to vary also under high pressures, but the variation within the pressure range in which we are generally interested is inconsequential.

pipe (D). We may select this at random with the assurance that, if we have made a poor selection, the lack of economy will become evident before we have gone very far.

To best illustrate the use of the charts let us take a practical example. It is desired to fill a 1-m.g. covered reservoir in four hours [*i.e.* at a rate (Q) of about 9.28 c.f.s.] from a pond 200 ft. below it and 6200 ft. away, the average yearly temperature of the water being about 55°F. Included in the line are three standard tees, eight 45-degree elbows, four long-radius elbows and two gate valves. Assume the diameter of pipe to be 6 in. From Figure 4, the equivalent length of the fittings in straight pipe for a diameter of 6 in. is as follows:

3 standard tees	3 x 11 = 33
8 45° elbows	8 x 7.5 = 60
4 long-radius elbows	4 x 11 = 44
2 gate valves	2 x 3.5 = 7
	144 ft.
Straight pipe	6200 ft.
	6344 ft., say L = 6350 ft.

The viscosity of water at 55°F. is about 0.0121 poise or dyne second per sq. cm. and the density at the same temperature is about 0.99 gram per c.c. By placing a triangle on Figure 1, we find the value of 10^3 x kinematic viscosity to be about 0.013.

From Figure 2, using this value for the kinematic viscosity and Q = 9.28 c.f.s. as well as D = 6 in., we find Reynolds Number R_e = 1,900,000.

From Figure 3, using clean galvanized iron pipe, the friction factor (f) is approximately 0.015.

From Figure 5, with L = 6350 ft., D = 6 in., Q = 9.28 c.f.s and f = 0.015, we find h_f, the head loss due to friction to be in the vicinity of 5000 ft. It becomes immediately apparent without having done much work that we have made a poor assumption for D which gave us an excessively high head loss. Let us assume that D is 12 in.

From Figure 4, the equivalent length of the fittings is:

3 standard tees	3 x 20 = 60
8 45° elbows	8 x 15 = 120
4 long-radius elbows	4 x 20 = 80
2 gate valves	2 x 7 = 14
	174
Straight pipe	6200
	6374, say L = 6400

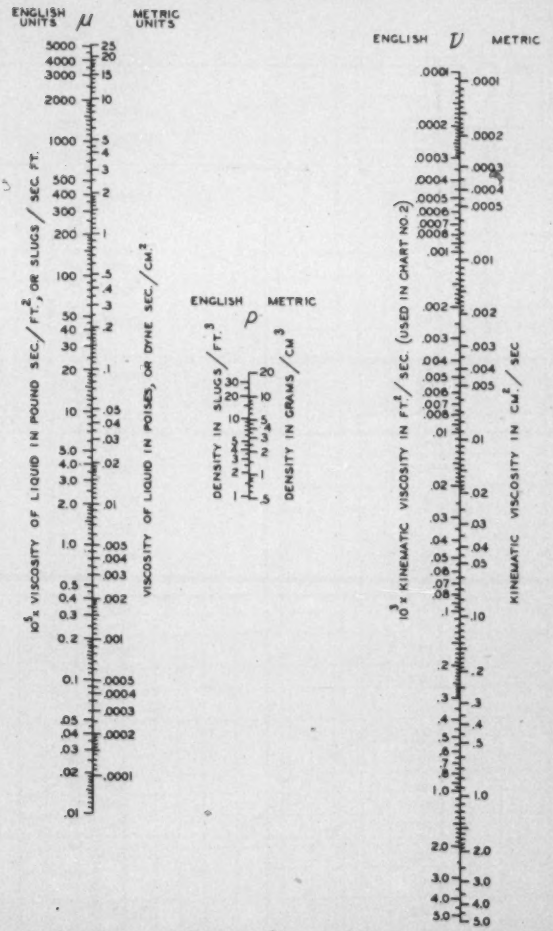

ENGLISH UNITS μ METRIC UNITS
10⁵ x VISCOSITY OF LIQUID IN POUND SEC./FT.², OR SLUGS/SEC. FT.
VISCOSITY OF LIQUID IN POISES, OR DYNE SEC./CM.²
ENGLISH ρ METRIC
DENSITY IN SLUGS/FT.³
DENSITY IN GRAMS/CM.³
ENGLISH ν METRIC
10³ x KINEMATIC VISCOSITY IN FT.²/SEC. (USED IN CHART NO. 2)
KINEMATIC VISCOSITY IN CM.²/SEC.

FIG. 1—TO FIND KINEMATIC VISCOSITY, USED IN DETERMINING REYNOLDS NUMBER.

$$\nu = \frac{\mu}{\rho} = \text{kinematic viscosity}$$

μ = viscosity

ρ = density

Note: The "slug" is the mass to which an acceleration of one ft. per sec. would be given by the application of a one-pound force. For all practical purposes, one slug of mass = 32.2 lb. of mass; therefore the weight of a cu. ft. of liquid divided by 32.2 will give the density in "slugs".

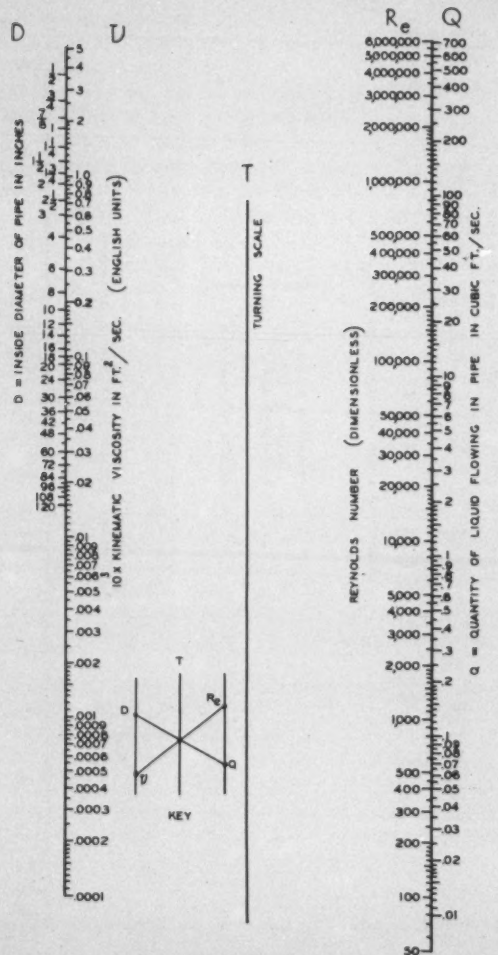


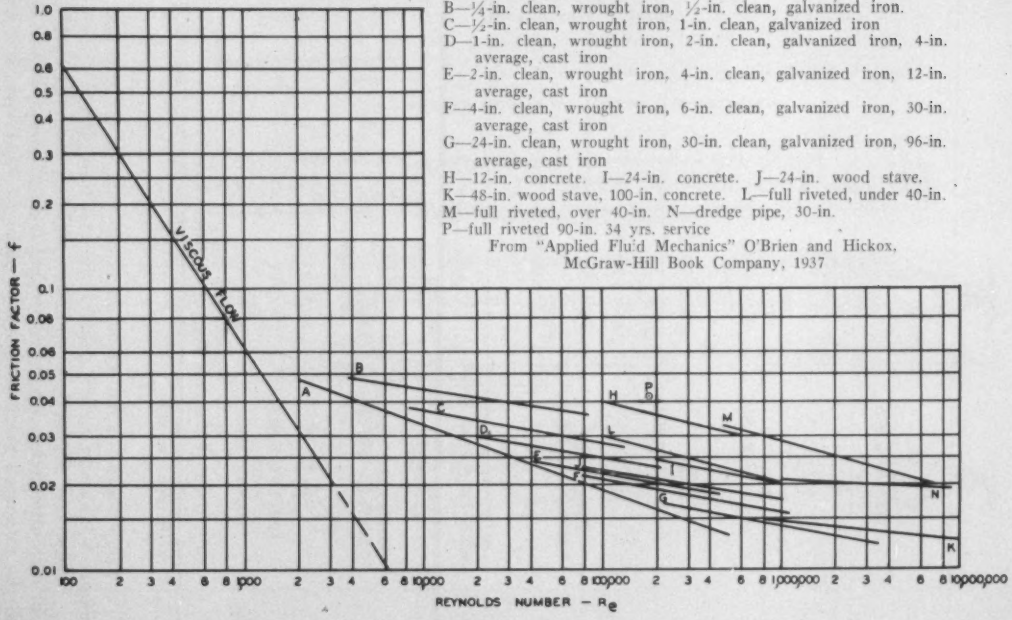
FIG. 2—TO FIND REYNOLDS NUMBER, USED IN DETERMINING THE FRICTION FACTOR f FOR LIQUIDS FLOWING IN PIPES.

$$R_e = \frac{4Q}{\pi D \nu}$$

FIG. 3—FRICTION FACTOR VERSUS REYNOLDS NUMBER

A—smooth pipes, lead, brass, tin, glass
B—¼-in. clean, wrought iron, ½-in. clean, galvanized iron.
C—½-in. clean, wrought iron, 1-in. clean, galvanized iron
D—1-in. clean, wrought iron, 2-in. clean, galvanized iron, 4-in. average, cast iron
E—2-in. clean, wrought iron, 4-in. clean, galvanized iron, 12-in. average, cast iron
F—4-in. clean, wrought iron, 6-in. clean, galvanized iron, 30-in. average, cast iron
G—24-in. clean, wrought iron, 30-in. clean, galvanized iron, 96-in. average, cast iron
H—12-in. concrete. I—24-in. concrete. J—24-in. wood stave.
K—48-in. wood stave, 100-in. concrete. L—full riveted, under 40-in.
M—full riveted, over 40-in. N—dredge pipe, 30-in.
P—full riveted 90-in. 34 yrs. service

From "Applied Fluid Mechanics" O'Brien and Hickox, McGraw-Hill Book Company, 1937



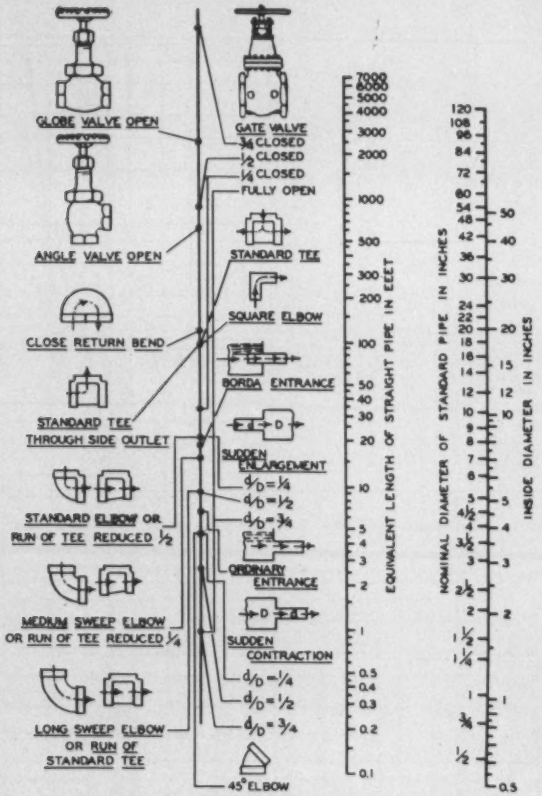


FIG. 4—TO FIND EQUIVALENT LENGTH FOR FITTINGS

Note: For sudden enlargements or sudden contractions use the smaller diameter "d" on the pipe size scale.

From Crane Co. Catalog.

From Figure 2, the Reynolds Number R_e is 900,000 and from Figure 3 f is about 0.0175, using 12-in. cast-iron pipe.

Now from Figure 5, $h_f = 220$ ft. which is more reasonable. For our own satisfaction, we may now find from Figure 5 what a change in the estimated value of f would mean in head loss, and we can easily see that the effect of changes in the friction factor (within

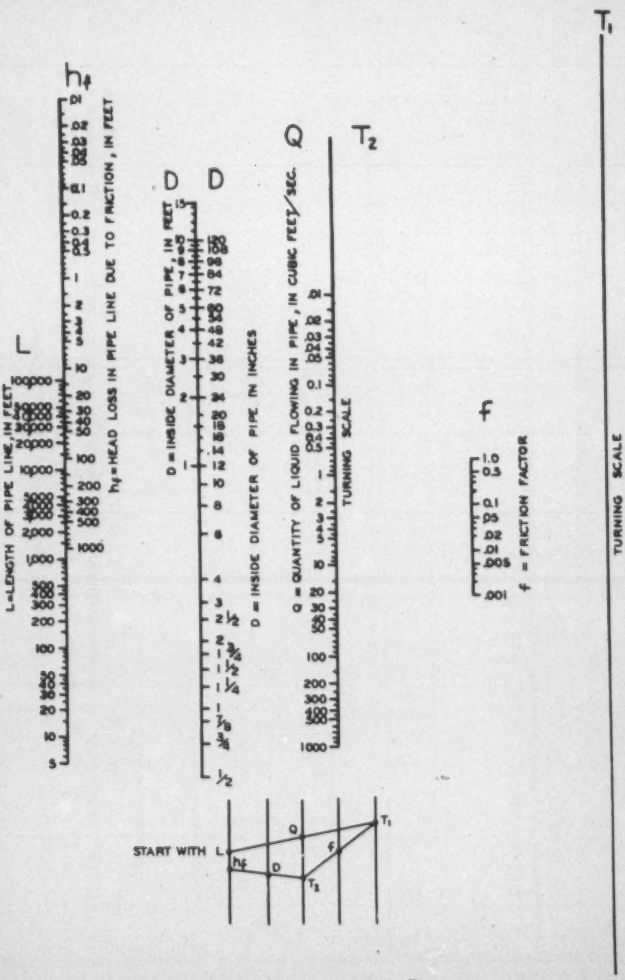

L=LENGTH OF PIPE LINE, IN FEET
h_f=HEAD LOSS IN PIPE LINE DUE TO FRICTION, IN FEET
D = INSIDE DIAMETER OF PIPE, IN FEET
D = INSIDE DIAMETER OF PIPE IN INCHES
Q = QUANTITY OF LIQUID FLOWING IN PIPE, IN CUBIC FEET/SEC.
TURNING SCALE
f = FRICTION FACTOR
TURNING SCALE
START WITH L
Q
f
h_f
D
T_1
T_2

FIG. 5—TO FIND HEAD LOSS OR DIAMETER

$$h_f = 0.0252 f \frac{L}{D^5} Q^2$$

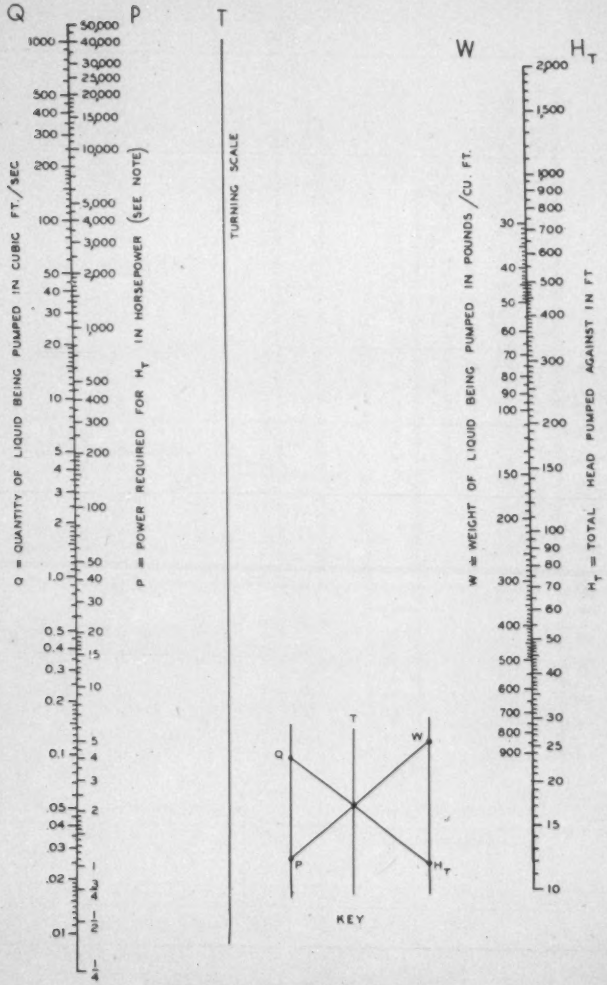

Q
P
T
W
H_T
Q = QUANTITY OF LIQUID BEING PUMPED IN CUBIC FT./SEC.
P = POWER REQUIRED FOR H_T IN HORSEPOWER (SEE NOTE)
TURNING SCALE
W = WEIGHT OF LIQUID BEING PUMPED IN POUNDS/CU. FT.
H_T = TOTAL HEAD PUMPED AGAINST IN FT
KEY

FIG. 6—TO FIND POWER REQUIRED

Note: Pump efficiency has not been taken into account.

$$P = \frac{WH_TQ}{550}$$

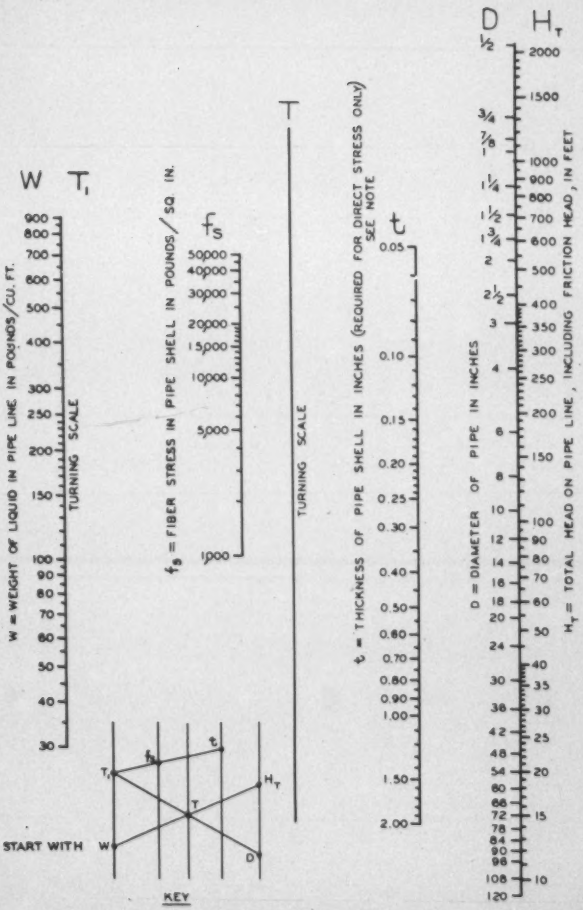

W
T_1
W = WEIGHT OF LIQUID IN PIPE LINE IN POUNDS/CU. FT.
TURNING SCALE
f_s
f_s = FIBER STRESS IN PIPE SHELL IN POUNDS/SQ. IN.
T
TURNING SCALE
t
t = THICKNESS OF PIPE SHELL IN INCHES (REQUIRED FOR DIRECT STRESS ONLY) SEE NOTE
D
H_T
D = DIAMETER OF PIPE IN INCHES
H_T = TOTAL HEAD ON PIPE LINE, INCLUDING FRICTION HEAD, IN FEET
START WITH W
KEY

FIG. 7—TO FIND THICKNESS OF PIPE

Note: Increase thickness of pipe shell by the proper amount, added to "t", to take care of corrosion, stiffness, joint efficiency, shock and other factors where applicable.

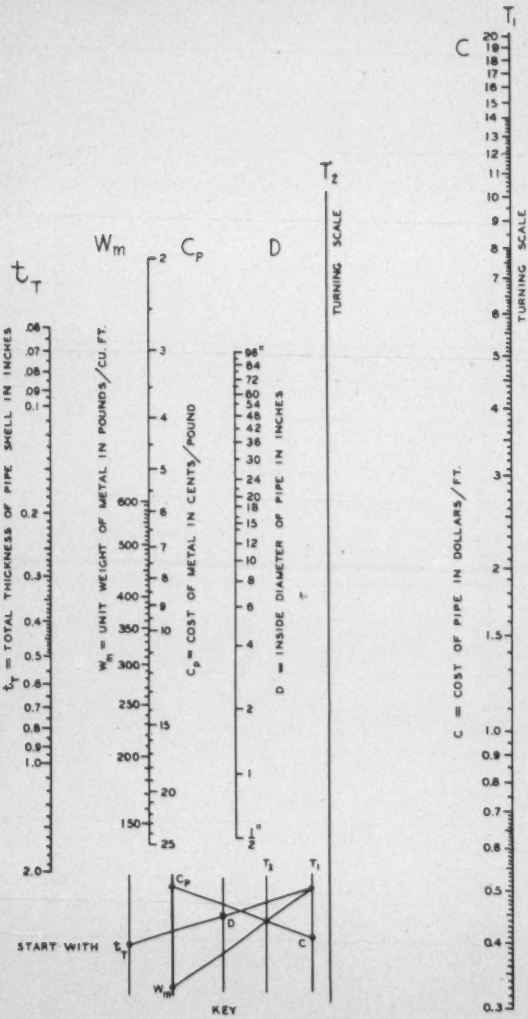


FIG. 8—TO FIND COMPARATIVE PIPE COST

$$C = \frac{W(D+t_T)t_T C_p}{144}$$

reasonable limits) is of considerably less magnitude than the effect of changes in diameter; therefore that the economics of the problem will be settled by variations in diameter and not by selecting f exactly correct.

The total head that we must pump against (H_t) is the friction head plus the head due to difference in elevation between the pond and the covered reservoir or 420 ft. From Figure 6, we find that the power required will be about 450 h.p. neglecting pump efficiency or possibly 560 h.p. considering pump efficiency.

Assuming that we select A.W.W.A. Standard Bell and Spigot Class E pipe with a thickness (t_T) of 0.82 in. and assuming a weight $W = 450\#/\text{cu. ft.}$ and a cost per pound $Cp = 10¢$ (including cost of installation), then the cost per foot C, from Figure 8, is about \$9.70. The total cost, therefore, is approximately \$62,200 for pipe and fittings, and approximately \$64,500 with valves.

If we were designing a large line of riveted steel pipe or the line just discussed but of a different material, we could find the thickness of pipe shell required for direct stress, for any assumed fiber stress, from Figure 7. This thickness, when adjusted for joint efficiency, corrosion, shock, stiffness or other factors as required would then be used as t_T in Figure 8 to find the cost of the pipe per foot.

We can now run through the charts again, assuming $D = 14$ in. and $D = 10$ in. The results are noted in the following schedule. It might be well to point out here that for all practical purposes these same figures could have been obtained directly from Figure 5 without retracing any steps, because having found our point on turning scale T_2 the values of h_f for any D could have been picked off directly. It must be appreciated that this is approximate, but the schedule shows that f does not change radically with changes in diameter, at least where fluids other than viscous fluids are concerned.

D inches	R_e	f	h_f ft.	H_t ft.	Power required hp.	Pipe	t_T in.	C Dollars per ft.	Approx. comparative cost of pipe fittings & valves
10	1,100,000	0.017	505	705	940	H	0.92	9.10	\$60,000
12	900,000	0.0175	220	420	560	E	0.82	9.70	64,500
14	800,000	0.0175	105	305	400	D	0.82	11.40	75,500

As the diameter increases, the cost of pipe increases and the initial cost of pumping equipment and the annual cost of power needed

for pumping decreases. The questions of pumping cost involves so many variables that it falls outside the scope of this paper but with the pumping factor taken into consideration, it is a simple matter to tell which layout will be the most economical to use. It will be noted from the schedule that going from a 10-in. to a 12-in. pipe did not materially increase the cost of pipe but did cut down the power required for pumping appreciably. If the pipe was made of a different material the size selected might possibly be changed. The required answer may be obtained just as readily as before. Gravity flow might result in a different diameter also.

If we had the problem of delivering 9.28 c.f.s. of water from the storage reservoir through a pipe line of the same length and with the same fittings, valves, etc. as before to a discharge point 200 ft. below the reservoir at a final pressure of 40 lb. per sq. in., the economics of the problem would have demanded that we use the smallest pipe possible for the head (h_f) available. This answer can be determined directly from Figure 5: $h_f = 200 - 40 \times 2.308 = 107$ ft. and the pipe diameter would have to be 14 in.

The design for pipes carrying liquids other than water is carried out in the same manner as that for water, starting out with the appropriate values of viscosity and density for the liquid under consideration, being very careful to use the proper units in Figure 1. Note that no change of decimal point is required in using 10^3 x kinematic viscosity (English units) from Figure 1 in Figure 2.

The viscosity and density of liquids may be found in most tables of physical and chemical constants.

Summary of Use of Charts. All unknown values are determined by connecting the known quantities by a system of straight lines in the arrangement shown in the key. Where no key is shown there is no turning scale and one straight line gives the answer directly.

FIGURE 1—KINEMATIC VISCOSITY

Given: μ = Viscosity of liquid at a given temperature
ρ = density of liquid in the Metric or English system of units.
Find: $10^3\nu$ = 10^3 x kinematic viscosity in English units (sq. ft. per sec.)

Note: If the kinematic viscosity is known in metric units, conversion may be made from the chart directly into the English equivalent.

FIGURE 2—REYNOLDS NUMBER

Given: D = Inside Diameter of Pipe (in.)
Q = Quantity of liquid flowing in pipe (c.f.s.)
$10^3\nu$ = 10^3 x kinematic viscosity (sq. ft. per sec.).
Find: Reynolds Number (dimensionless in any consistent set of units).

FIGURE 3—FRICTION FACTOR

Given: Reynolds Number.
Find: Friction factor f.

FIGURE 4—EQUIVALENT LENGTH OF FITTINGS

Given: Number of Various Types of Fittings,
D = Inside Diameter of Pipe (in.).
Find: Equivalent length of fittings in straight pipe (ft.).

FIGURE 5—HEAD LOSS OR DIAMETER

Given: L = Equivalent length of Straight pipe (ft.),
Q = Quantity of liquid flowing in pipe (c.f.s.),
f = Friction factor,
D = Inside diameter of pipe (in.).
Find: h_f = lost head in pipe line due to friction where pumping is required, or h_f = head available to lose in gravity flow (in this case D is the unknown).

FIGURE 6—POWER REQUIRED

Given: Q = Quantity of liquid being pumped (c.f.s.),
H_T = Total head pumped against (ft.), or
$H_T = h_f$ (Head due to friction) + h_e (Head due to difference in elevation),
W = Unit weight of liquid being pumped (lb. per cu. ft.).
Find: Horse power required.

FIGURE 7—THICKNESS OF PIPE

Given: W = Weight of liquid in pipe line (lb. per cu. ft.),
H_T = Total head on pipe line, including friction head (ft.),
D = Diameter of pipe (in.),
f_s = Fiber stress in pipe shell (lb. per sq. in.),
Find: t = Thickness of pipe shell required for direct stress (in.).

FIGURE 8—COMPARATIVE PIPE COST

Given: t_T = Total thickness of pipe shell required (in.), or
$t_T = t$ + thickness factors,
D = Inside diameter of pipe (in.),
W = Unit weight of metal (lb. per cubic ft.),
C_p = Cost of metal (cents per pound) (Includes the cost of installation).
Find: C = Cost of pipe (dollars per ft.).

PROCEEDINGS

NOVEMBER 1938 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, November 17, 1938.

President George A Sampson in the chair.

The PRESIDENT. Since our last meeting of the Association one of the most loyal members of the Association, Patrick Gear, Superintendent of the Holyoke Water Department, passed away on October 24. We shall all miss his genial friendship and ready wit. Let us rise for a moment in silent tribute to Patrick Gear.

[The members stand in silence.]

The Executive Committee at a meeting this morning, according to the constitution, appointed as Secretary, Frank J. Gifford, and as Editor, Gordon M. Fair.

Karl R. Kennison, who has been chairman of the Program Committee, on account of other duties has found it impossible to continue in this capacity, and Samuel M. Ellsworth has consented to take the chairmanship of this committee together with its numerous problems. The other members of the committee are Sidney S. Anthony, Harold L. Brigham, E. Sherman Chase, and Gordon M. Fair.

Secretary GIFFORD announced the election to membership by the Executive Committee of the following:

Junior Member

John Joseph Baffa, Brooklyn, New York.

Associate

Youngstown Sheet & Tube Co., Boston, Massachusetts.

A paper, "Standby Emergency Power Equipment for Pumping Stations," was read by Charles E. Greene, Consulting Engineer, Boston, Mass. Percy A. Shaw took part in the discussion.

A paper, "Safeguarding Rhode Island Water Supplies against Future Disasters," was read by James J. Dillon, Sanitary Engineer and Chemist, Rhode Island Department of Public Health.

A paper, "Protection of Public Water Supplies in Massachusetts during the Floods and Hurricane," was read by Joseph Knox, Assistant Engineer, Massachusetts Department of Public Health.

These two papers were discussed by Percy A. Shaw, Warren J. Scott, James V. Turner, Francis H. Kingsbury, Stephen H. Taylor, Percy A. Charnock, and Henry E. Halpin.

DECEMBER 1938 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, December 15, 1938.

President George A. Sampson in the chair.

The PRESIDENT. Since our last meeting we have lost by death two members of the Association:

William P. Molis, Superintendent of the Muscatine, Iowa, Water Department, died on November 27 at the age of eighty-three years. Mr. Molis joined the Association on June 17, 1887, and at the time of his death was one of the oldest living members of the Association.

Allen W. Cuddeback, until last spring President of the New York Water Service Corporation, died on December 4. Mr. Cuddeback joined the Association on June 10, 1900.

Let us rise a moment in silent memory to these two members of the Association.

[The members stand in silence.]

Secretary GIFFORD. Members elected this morning at the meeting of the Executive Committee are as follows:

Members: John A. Miller, Superintendent, Water Department, Warwick, Rhode Island; Frederick H. Miller, Superintendent, Water Department, Norton, Mass.; Ellis A. Tarlton, Superintendent and Chemist, Salem-Beverly, Filtration Plant, Beverly, Mass.

Corporate Member: Warwick Water Department, Warwick, Rhode Island.

The Secretary read the following Report of the Committee to Consider a Revision of the Method of Bookkeeping now Being Followed by the Association:

"After a study of the Treasurer's records, the Committee feels that nothing is to be gained by changing the records as now kept by the Treasurer, and particularly so since he had already started a new and slightly different cash book, enabling him to keep in one book records that formerly required two books of account."

(Signed) D. C. Calderwood, Chairman.
Leland G. Carlton
Abel Reynolds.

On motion of Richard H. Ellis, duly seconded, it was VOTED that the report of the committee be accepted and placed on file. On motion of E. Sherman Chase, duly seconded, it was VOTED to discharge the committee.

A paper, "The Use of Lined and Wrapped Steel Pipe by the Augusta Water District," was read by Sidney S. Anthony, Superintendent and Engineer, Augusta Water District, Augusta, Maine.

A paper, "Laying Lined and Wrapped Steel Pipe at Needham, Mass.," was read by Roger G. Oakham, Superintendent, Needham Water Department, Needham, Mass.

These two papers were discussed by Donald C. Calderwood, George F. Merrill, and Allen M. Symonds.

Edward W. Moore, Assistant Professor of Sanitary Chemistry, Harvard Graduate School of Engineering, spoke on "Determination of Chemical Dosages for Prevention of Corrosion." Robert Spurr Weston, George F. Merrill, Stephen H. Taylor, Warren J. Scott, Linn H. Enslow, David E. Moulton, Ralph E. Runels, Allen M. Symonds, and Everett M. Battey took part in the discussion.

A moving picture, "The Manufacture of Steel Pipe," was presented by The Youngstown Sheet and Tube Company.

JANUARY 1939 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, January 19, 1939.

President George A. Sampson in the chair.

Secretary Gifford announced the election by the Executive Committee of the following new members:

Members. Peter S. Sinclair, Water Commissioner, Holyoke, Mass.; William T. Barry, Acting Superintendent, Water Department, Holyoke, Mass.; Walter M. Hatch, Superintendent, Water Works, Braintree, Mass.; Edmund C. Knight, Senior Sanitary Engineering Aid, Water Supply Division, Metropolitan District Commission, Boston, Mass.; Edward F. Jerome, Superintendent, Water Supply District, Leicester, Mass.; Edward Stickney Brown, Jr., Instructor in Sanitary Engineering, Thayer School of Civil Engineering, Hanover, N. H.; Jorge Vicentini Gutierrez, Assistant to George C. Bunker, Iron Removal Plant, Caracas, Venezuela.

Associate. Hill, Hubbell & Co., Division, General Paint Corporation, Cleveland, Ohio.

A talk, "Federal Taxation of State and Municipal Securities and Salaries," was given by Henry F. Long, Commissioner of Corporations and Taxation for the Commonwealth of Massachusetts.

On motion of Charles W. Sherman a rising vote of thanks was given to Commissioner Long in appreciation of his admirable address.

The balance of the session was devoted to a Round Table discussion of "Copper Tubing for House Services." A paper, "A Summary of Corrosion Experiments," was read by Harry M. Clark, Associate, Whitman & Howard, Engineers, Boston, Mass. Arthur R. G. Booth, Francis H. Kingsbury, D. S. Norris, Roger W. Esty, F. G. Smith, Donald G. Calderwood, Percy R. Sanders, Carter S. Cole, and Edward W. Moore took part in the discussion.

FEBRUARY 1939 MEETING

HOTEL STATLER, BOSTON, MASS.

February 16, 1939.

President George A. Sampson in the chair.

The PRESIDENT announced the death of the following members:

Leigh I. Holdredge of Oneonta, N. Y., died on November 11, 1938. Mr. Holdredge was District Sanitary Engineer of the New York State Department of Health. He became a member of this Association in 1937.

Robert Ridgway of New York City, Consulting Engineer, died on December 19, 1938. Mr. Ridgway was a Past President of the American Society of Civil Engineers, and an Honorary Member. He became a member of this Association in 1908.

Frank E. Winsor of Newton, Mass., Chief Engineer of the Metropolitan District Water Supply Commission, died on January 30, 1939. Mr. Winsor was elected a member of this Association in 1900, was its president in 1926-1927, and was elected an Honorary Member in 1935.

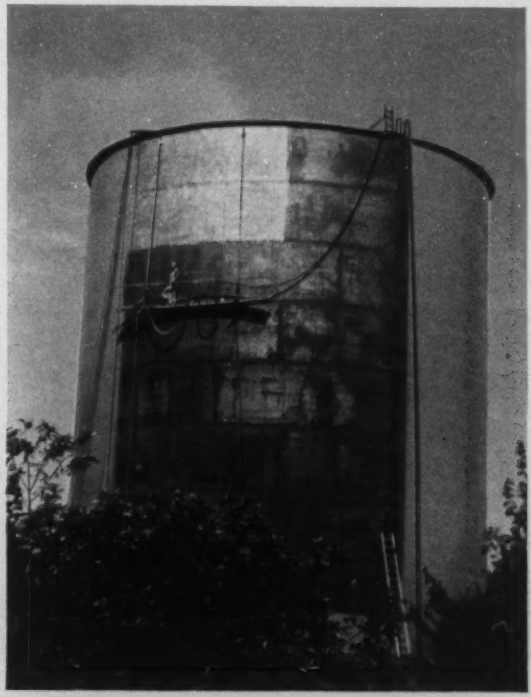
Will the members please rise in memory of these men?

[The members stand in silence.]

Secretary Gifford announced the election to membership by the Executive Committee of David P. Geary, Water Registrar, Arlington, Mass.

A paper, "The Restoration of Watershed Forests in the Hurricane Area," was read by A. C. Cline, Assistant Director, Harvard Forest, Petersham, Mass. Roger W. Esty and two other members took part in the discussion.

A paper, "Cleaning and Relining of Water Mains in Place," was read by Bruce Harkness, American Representative of Tate Water Lining Processes, Ltd., Andover, Mass. A written discussion prepared by Thomas H. Wiggin, Consulting Engineer, New York City, entitled "Some Observations on the Relining of Water Mains in Place," was read by Charles W. Sherman. A paper was also read by H. Seaver Jones of T. A. Gillespie Company. Richard H. Ellis and other members took part in the general discussion.



Photograph by W. J. Lumbert

The first and largest all butt-welded
Standpipe in New England

SANDBLASTED AND PAINTED

by

J. H. TREDENNICK, INC.

10 HIGH STREET
BOSTON, MASS.
Telephones: Liberty 2480—Parkway 0285

STANDPIPE PAINTING

The problem of painting your standpipe, in all probability, does not involve the costly treatment pictured on the preceding page. This procedure is recommended only for new standpipes, standpipes previously painted over mill scale, and those not painted for so long that they are badly pitted.

The ordinary repaint job requires good paint, a thorough cleaning job, and experienced and trained artesans. The leading paint manufacturers have spent years in experimentation and millions of dollars in developing paints to meet your requirements. J. H. TREDENNICK, INC., has spent over thirty years in developing the most up-to-date cleaning methods and training men in the best painting technique. Our power wire brushing system is known throughout New England, and we suggest that you seek your paint supplier's opinion regarding the advisability, the economy, and even the necessity of our thorough cleaning methods.

We have successfully completed the painting of the following standpipes, during the past two seasons:

Westerly
East Providence
North Attleboro
Hanover
Scituate
Marshfield
Quincy
Marblehead
Brookfield
Winthrop
Reading

We number among our customers such consumers as:

American Oil Company
Gulf Oil Corporation
Atlantic Refining Company
New England Power Company
Stone & Webster, Incorporated
General Electric Company

Should you wish to discuss the maintenance of your standpipe, call or write

J. H. TREDENNICK, INC.

10 HIGH STREET

BOSTON, MASS.

Telephones: Liberty 2480 Parkway 0285

INDEX OF ADVERTISERS

	Page
Atlas Mineral Products Co.	xxvi
Bailey, Howard E.	iii
Barbour, Frank A.	ii
Barrows, H. K.	ii
Bingham & Taylor	iv
Brainard, F. S. & Co.	xxvii
Caldwell, George A., Co.	xxxv
Cement Lined Pipe Co.	viii
Crosby, Irving B.	iii
Darling Valve & Mfg. Co.	ix
Donaldson Iron Co.	xxiv
Dresser, S. R., Mfg. Co.	Following front cover
Eddy Valve Co.	xv
Edson Corp., The	xxii
Ellsworth, Samuel M.	ii
Fairbanks-Morse Co.	xxiv
Farnan Brass Works Co.	xxvii
Fay, Spofford & Thorndike	ii
Ford Meter Box Co.	xvii
Goodnough, X. Henry, Inc.	ii
Hays Mfg. Co.	xviii
Hersey Mfg. Co.	v
Hydraulic Development Corp.	x
Industrial Chemical Sales Division—West Virginia Pulp and Paper Co.	xix
Johns-Manville	xi
Keasbey & Mattison Co.	xxv
Kennedy Valve Mfg. Co.	xiv
Layne-Bowler New England Co.	iii
Leadite Co.	Back cover
Lock Joint Pipe Co.	Facing front cover
Ludlow Valve Mfg. Co.	xvii
Metcalf & Eddy	ii
Morris Machine Works	xxvi
Mueller Co.	xxxiii
National-Boston Lead Co.	xvi
National Gunite Contracting Co.	iii
National Meter Co.	xii
National Water Main Cleaning Co.	viii
Neptune Meter Co.	vi
New England Water Works Association	ii
Newsom, Reeves	ii
Pierce-Perry Co.	viii
Pirnie, Malcolm	ii
Pitometer Company	ii
Pittsburg Equitable Meter Co.	Following front cover
Red Hed Mfg. Co.	xxxiv
Rensselaer Valve Co.	xxiii
Reppucci, C. & Sons, Inc.	iii
Ross Valve Mfg. Co.	viii
Smith, The A. P., Mfg. Co.	xvii
Tredennick, J. H., Inc.	Preceding index of advertisers
Turbine Equipment Co.	xx
U. S. Pipe and Foundry Co.	Facing back cover
Wailes Dove-Hermiston Corp.	xxiii
Wallace & Tiernan	xxi
Warren Foundry and Pipe Corp.	xxii
Weston & Sampson	iii
Whitman & Howard	iii
Wood, R. D., Co.	xxviii
Worthington Pump and Machinery Corp.	vii

(Classified index on page xxix)

ENGINEERS

FRANK A. BARBOUR
Consulting Engineer

Water Supply, Water Purification, Sewer and Sewage Disposal, Valuations

Tremont Building, Boston, Mass.

H. K. BARROWS
M. Am. Soc. C. E.
Consulting Hydraulic Engineer

Water Power, Water Supply, Sewerage, Drainage, Investigations, Reports, Valuations, Designs, Supervision of Construction

BOSTON, MASS. 6 BEACON ST.

Samuel M. Ellsworth
M. Am. Soc. C. E.
Consulting Engineer
Water Supply and Sewerage
Investigations, Reports and Designs, Supervision of Construction and Operation
12 Pearl Street, Boston

FAY, SPOFFORD & THORNDIKE
ENGINEERS
Frederic H. Fay — Charles M. Spofford
John Ayer — Bion A. Bowman
Carroll A. Farwell — Ralph W. Horne
Water Supply—Sewerage—Drainage
Structural and Foundation Problems
Investigations Reports Designs Valuations
Engineering Supervision
11 BEACON STREET BOSTON

THE PITOMETER COMPANY
ENGINEERS
Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Penstock Gaugings
50 Church Street New York City

REEVES NEWSOM
Engineer-Consultant
WATER WORKS—SEWERAGE
Construction and Operation
Investigation and Design
Valuation and Rates
500 Fifth Avenue New York

X. HENRY GOODNOUGH, Inc.
Engineers
BAYARD F. SNOW
Water Supply, Drainage, Sewerage, Sewage Disposal, River Improvement, Disposal of Municipal and Industrial Wastes
14 BEACON ST. BOSTON, MASS.

METCALF & EDDY
ENGINEERS
Water, Sewage, Drainage, Garbage and Industrial Wastes Problems
Laboratories Valuations
BOSTON, MASS.
Statler Building

MALCOLM PIRNIE
ENGINEER
Water Supply, Treatment, Sewerage
Reports, Plans, Estimates,
Supervision and Operation,
Valuation and Rates.
25 West 43rd Street, New York, N. Y.

WATER WORKS CONTRACTORS AND SUPPLY HOUSES

Your card may be inserted in this space for $12 per year

ENGINEERS

WESTON & SAMPSON

Consulting Engineers

Robert Spurr Weston George A. Sampson

Water Supply and Sewerage
Chemical and Bacteriological Laboratory

14 BEACON ST. BOSTON, MASS.

WHITMAN & HOWARD

HARRY W. CLARK, Associate

Civil Engineers

(Est. 1869. Inc. 1924.)

Investigations, Designs, Estimates, Reports and Supervision, Valuations, etc., in all Water Works and Sewerage Problems

89 BROAD ST. BOSTON, MASS.

IRVING B. CROSBY

Consulting Engineering Geologist

Investigations of Dam and Reservoir Sites and Groundwater Supplies

6 BEACON ST. BOSTON, MASS.

HOWARD E. BAILEY

Consulting Sanitary Engineer

Water Works Water Purification
Sewerage Sewage Treatment
Industrial Wastes Disposal

177 State St., Boston, Mass.

WATER WORKS CONTRACTORS

C. REPPUCCI & SONS, INC.

GENERAL CONTRACTORS

Ground Water Supply

Gravel Packed Wells Driven Wells
Water Works Reservoirs
Drainage and Sewerage Works

10 Garden Court Street (Tel. Lafayette 7330) Boston, Mass.

RESERVOIRS and TANKS LINED and RESTORED

with

GUNITE

NATIONAL GUNITE CONTRACTING COMPANY

Engineers and Contractors

82 W. Dedham St. BOSTON

Layne-Bowler New England Company, Inc.

Developers of High Capacity Patented Gravel Wall Wells

P. D. BOWLER, Pres.

Statler Building Boston Telephone Liberty 5795

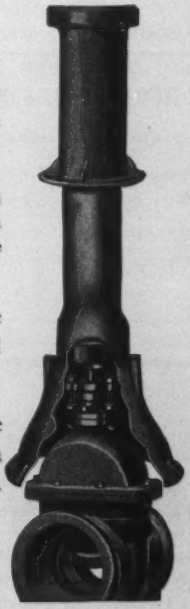
BINGHAM & TAYLOR'S Sliding Type Service and Valve Boxes are meeting with the approval of many New England Waterworks officials.

The cuts shown are our two and three piece sliding type adjustable valve boxes.

The flange on the bottom of the top section can be located any distance from the top.

We carry a complete stock on hand at all times.

Wire, phone or write us when you are in a hurry for a shipment.



Bingham and Taylor Corporation

MANUFACTURERS

575-601 Howard Street - - Buffalo, N. Y.

UNDER THE SEARCHING RAYS OF THE NATIONAL BOARD OF FIRE UNDERWRITERS SPOTLIGHT ALL

HERSEY DETECTOR METERS

STAND APPROVED

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

BRANCH OFFICES: NEW YORK · PORTLAND, ORE. · PHILADELPHIA · ATLANTA · DALLAS · CHICAGO · SAN FRANCISCO · LOS ANGELES

Like Trident Meter Quality

—it's there, even tho' you can't see it!

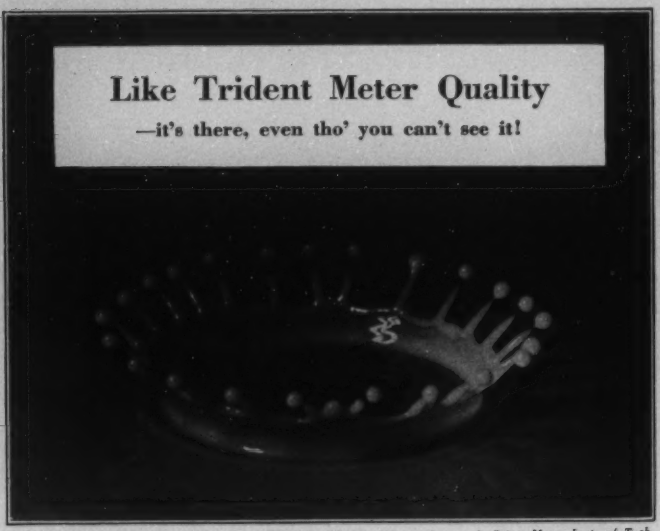


Photo by Edgerton, Germeshausen & Grier, Mass. Inst. of Tech.

Save for ultra-speed photography, you'd never see this "crown" created by a milk drop splash on a plate. We wish it were possible to show you the increased qualities in Trident Meters as vividly . . . we wish we could picture the closer tolerances, the finer finish, the standards of ultra-precision made possible by the modern precision machine tools and production methods used in the Neptune shops today. But you *can* easily see the *results* . . . in higher percentages and closer range of accuracy, perfect interchangeability, longer life, lower maintenance costs . . . these are the crowning proof of Trident Meter leadership.

FROST PROOF
With Breakable Bottom
Sizes ⅝" to 1"

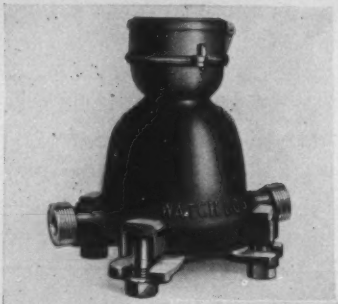
Trident

WATER METERS

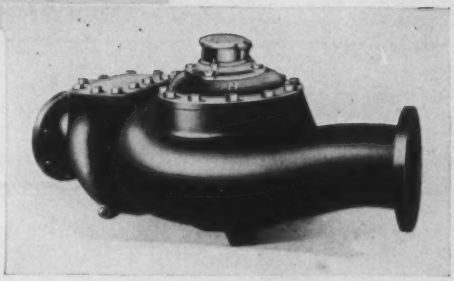
Neptune Meter Company, 50 West 50th St., Rockefeller Center, New York City; Neptune Meters, Ltd., 345 Sorauren Avenue, Toronto, Canada.

CREST
Velocity or inferential ty
with turbine or propeller f
high rates of flow
Sizes 1½" and 2" Screw En
1½" to 16" Flange End

WATCH DOG METERS



Frost-proof meter



Turbine meter

Investigate these meters

WHEN looking over your requirements, remember that thousands of municipalities are getting satisfactory low-cost service from Worthington-Gamon Meters.

WORTHINGTON-GAMON METER COMPANY

General Offices: HARRISON, NEW JERSEY

Offices and Representatives in Principal Cities

WORTHINGTON-GAMON

WGS-4

THE STANDARD FOR OVER 50 YEARS

Automatic Pressure Control Valves
Water Works Specialties

Altitude — Pressure Reducing — Surge
Relief and Combination Valves
Portable Fire Hydrants
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., Inc. Troy, N.Y.

Health and Protection First

Water delivered through dirty pipes
may be a MENACE.

Incrusted water pipes mean inefficiency
and loss of Fire Protection.

We Guarantee the Results of Our
Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.
50 Church Street New York City

Cement Lined Service Pipe

Cement lined pipe has eliminated corrosion and metal contamination for 60 years

Write for Literature

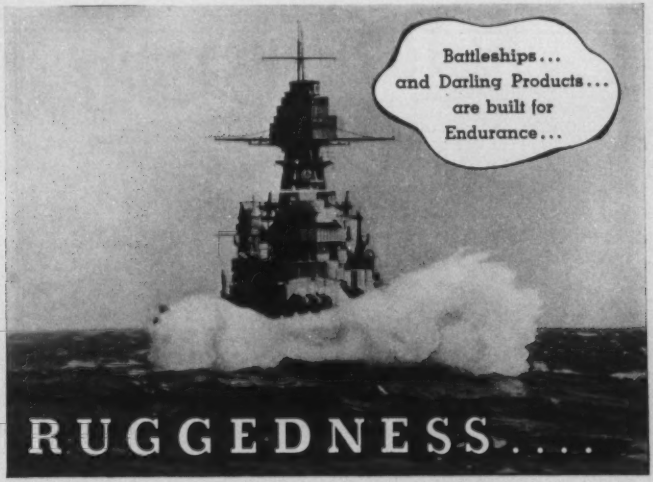
Cement Lined Pipe Co.
Lynn, Mass.

PIERCE - PERRY CO.

Wholesalers of

Water Works Brass Goods.
Byers Wrought Iron Pipe.
Youngstown Steel Pipe.
Valve and Service Boxes.

236 Congress St., Boston, Mass.
Telephone, Hancock 7817-7818



YOU CAN COUNT ON DARLING VALVES and Fire Hydrants for tough jobs—because that's the kind of work they're built for. Quality workmanship and sturdy construction insure real ruggedness in Darling Products—year after year.

Incidentally, this characteristic ruggedness means economy, because maintenance and repair costs are lowered.

The nearest Darling representative will be glad to talk about your particular problems. Of course, there is no obligation.

Six important features have won nationwide approval for Darling Hydrants.

The steadily increasing use of Darling Valves proves that performance outweighs promises.

DARLING VALVE & MFG. CO.
Williamsport, Pa.

Representatives in
New York Philadelphia Oklahoma City Houston Pittsburgh Toledo Evanston, Ill.

DARLING
GATE VALVES *and* FIRE HYDRANTS

"Never a Failure in Over 22 Years!"

WE like to talk about saving in material and labor—the strong, tight, flexible joints made with Hydro-Tite—the thousands of miles of pipe jointed with it.

More important, perhaps, is the fact that with hundreds of users—each laying pipe under different conditions—not a single one has reported a Hydro-Tite failure.

We make it very easy for you to change over to Hydro-Tite. Our Data Book outlines a novel proposition. Write for it.

A Symbol of Quality

A Dependable Self-Caulking Joint Compound

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office: 50 Church Street, New York, N. Y.
General Offices and Works: West Medford Station, Boston, Mass.

A THREE-WAY CUT IN WATER-CARRYING COSTS!

1. Saves on Installation

Transite Pipe is light. Every handling represents a saving. And Transite's Simplex Couplings, requiring no caulking, are rapidly and economically assembled by unskilled labor.

Result—profitable savings in time and money that lower installation costs!

2. Saves on Maintenance

Transite Pipe, because of its asbestos-cement composition, provides your best assurance of permanence. It is immune to electrolysis and tuberculation, highly resistant to soil corrosion.

Result—no cleaning expense, and a pipe that virtually eliminates costly shutdowns and renewals.

3. Saves on Pumping Costs

Because it cannot tuberculate under any circumstances, Transite Pipe maintains its initial high delivery capacity indefinitely. Its initial flow coefficient, conservatively estimated at C-140, remains at that figure throughout Transite's long years of service.

Result—pumping costs on Transite lines stay permanently low!

Hence Transite Pressure Pipe effects the three-way cut in water-carrying costs that promises you a permanently economical pipe line. Send for our free, illustrated brochure. It will tell you all you want to know about the advantages Transite offers to water transportation. Write to Johns-Manville, 22 East 40th Street, New York City, for your copy.

Johns-Manville
TRANSITE PRESSURE PIPE
An ASBESTOS Product

JM

WHY IS THE

EMPIRE *Measuring Chamber*

ACCURATE ON BOTH LARGE AND SMALL FLOWS?

For fifty-five years, the Empire Meter has been measuring flows both large and small with greater accuracy than any other meter ever manufactured . . .

because of the use of the time-tested positive displacement principle . . . one that consists of the continuous filling and emptying of a cylinder as constant in volume as a tester's measure.

because of the balanced piston . . . one so perfectly balanced that the actuating pressures can move it only in its normal circular direction . . . with negligible friction and entirely without strain.

. . . or, briefly, because of the sound principle of design . . . because it is easier for the water to push the piston ahead than it is to escape around it!

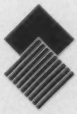
NATIONAL *Meters*

National Meter Company, 4207 First Avenue, Brooklyn, N. Y.

BOSTON CHICAGO DALLAS LOS ANGELES SAN FRANCISCO

Complete Service

is offered by our plant — from copy to the bound book. We have the facilities and experience necessary to assist you in preparing your printed matter, your magazine, or book. We know that we can be helpful and practical and the costs of the finished product are always fair.



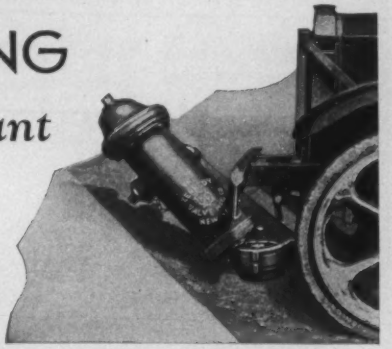
The Heffernan Press

150 Fremont Street

WORCESTER, MASS.

80% SAVING

in fire hydrant collision repair costs



Send for Bulletin

IMPACTS that would demolish any other type of fire hydrant merely fracture an inexpensive Safety Breakable Section of the Kennedy SAFE-TOP Fire Hydrant without injury to the major parts of the hydrant. The water pressure in the main keeps the inlet valve tightly closed so that there is no danger of flooding. No excavating is necessary, nor need the water service in the vicinity of the broken hydrant be shut off while awaiting or making repairs.

The only parts that need be renewed cost $6.00. They can be replaced by one man, with standard tools, in less than half an hour.

This unique design therefore provides the important multiple benefits of (1) minimum interruption to fire hydrant service after breakage, (2) elimination of cost and trouble of excavation, (3) inconsequential cost of hydrant repairs, (4) security from suspension of water service, and (5) protection against serious property damage and personal injuries.

Any style of fire hydrant now installed can be replaced by a Kennedy SAFETOP Fire Hydrant at low cost and without removing the existing hydrant elbow.

The Kennedy Valve Mfg. Co., Elmira, N. Y.

KENNEDY
SAFETOP FIRE HYDRANT

REG. U.S. PAT. OFF.

EDDY

Valves and Hydrants

Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

Distinctive Features of Our New Swivel Top Hydrants

THIS new hydrant has all the advantages of the popular EDDY fire hydrant, plus several additional features. . . . Nozzles are in a short flanged section of the standpipe, which may be unbolted and turned to different positions. . . . Should the standpipe be broken, only the casting below the swivel head need be replaced.

. . . To raise the hydrant to conform to a new grading, simply insert a flanged extension piece below the swivelhead. No digging. To add a steamer nozzle at any time, it is only necessary to replace the swivel head with one having a steamer nozzle.

Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

Eddy Valve Co.

WATERFORD **NEW YORK**

LEAD PIPE

Used by leading WATER WORKS for over 50 years. If proper weight is used, combined with good workmanship, your FINAL COST is assured, as REPAIRS are unnecessary. LEAD PIPE IS sufficiently ductile to conform to any sagging condition. There is no RUSTING of pipe or joints; no DISCOLORATION of water.

HIGHEST QUALITY SOFT OMAHA PIG LEAD

LEAD WOOL

Every atom pure lead

For calking pipe joints under the most difficult conditions.

RED LEAD

For rust-proofing tanks and pipes.

Write for Water Works specifications.

PURE BLOCK TIN PIPE TIN-LINED LEAD PIPE

DUTCH BOY WHITE LEAD

SOLDER

National-Boston Lead Co.

800 Albany Street Boston, Mass.

THE BEST
Hydrant
PROVIDES
Proper Drainage

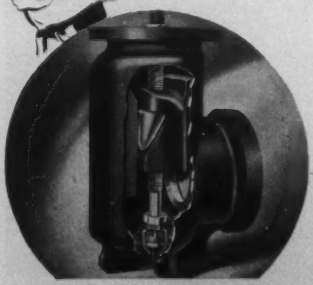
A hydrant must drain *completely* to guarantee constant readiness for service in cold weather. The best hydrant assures proper drainage with drain at the *lowest* point, opening with the last few turns as the hydrant is shut off.

The best hydrant also provides *quick* water with least possible shock, and shut-off without water hammer. It will not flood when broken, because the gate is wedge-locked. It is easily inspected and serviced *without unscrewing anything* below the ground level.

Only the slide gate principle provides *all* these advantages. This principle, developed and perfected by Ludlow, has been the universally accepted construction in all *water works valves* for nearly three-quarters of a century. It likewise insures *complete security* in fire hydrants.

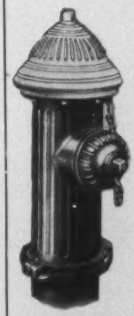
Full information free on request.

After gate is fully closed and wedged, drip valve opens assuring complete drainage below gate at lowest point in barrel.



The LUDLOW VALVE MFG·CO· SINCE 1866 TROY·N·Y·

"PROTECTOP"
FOR MINIMUM TROUBLE AND EXPENSE



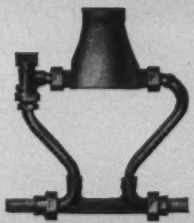
The SMITH PROTECTOP Safety Coupling Standpipe is designed to permit repairs incident to collision to be made in less than fifteen minutes at a minimum cost.

After collision, the only parts necessary to replace are the standpipe clamp and the hydrant stem frangible coupling.

The hydrant valve, being of the compression type and guided throughout its travel, will remain closed. Even if it is open at the time of collision it will close instantly thus preventing flooding of streets.

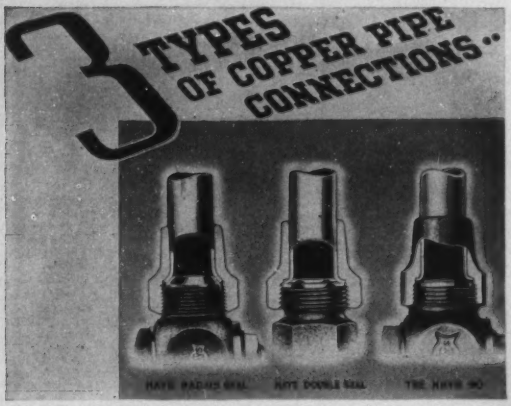
SMITH
WATER WORKS SPECIALTIES & SUPPLIES
THE A.P. SMITH MFG. CO. East Orange, N.J.

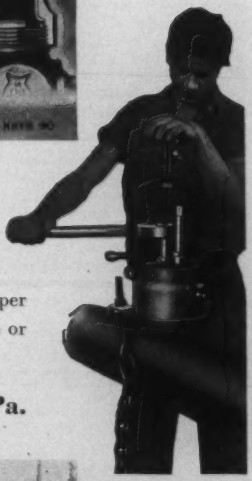
The Coppersetter
A COMPLETE METER MOUNTING



The COPPERSETTER is a simple, convenient and durable fitting for installing water meters in horizontal service lines. It is all brass and copper, made in several heights and can be provided with an inverted ground-key angle valve at the meter inlet. Write for more information about the COPPERSETTER.

The Ford Meter Box Co.
WABASH, INDIANA



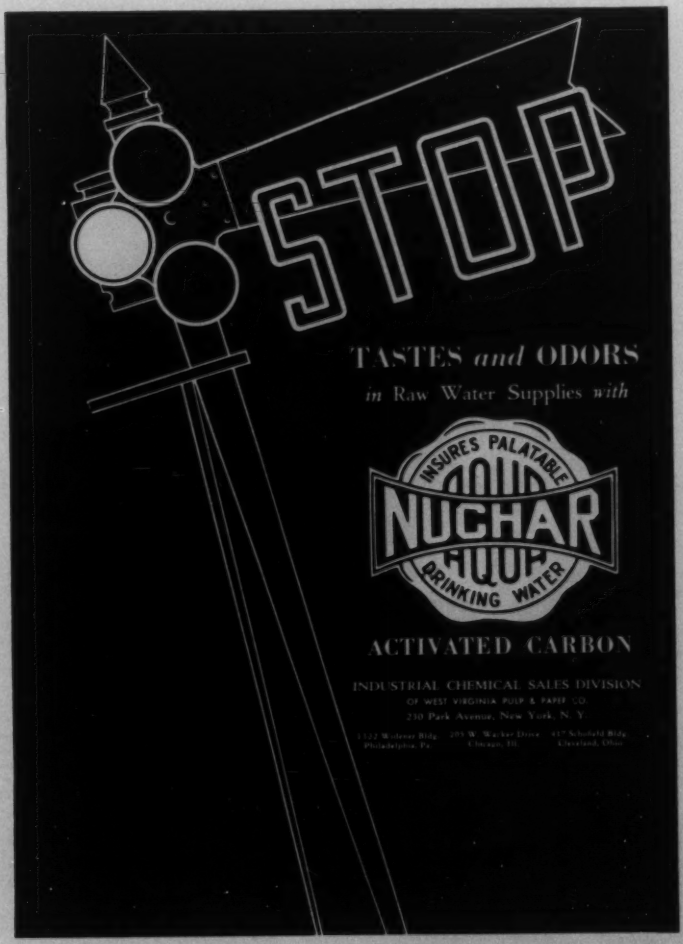


Whatever tapping method or type of corporation cock your city uses, Hays can take off with copper pipe to the curb or to the meter. Hundreds of water works departments have found Hays permanent copper services readily adaptable to their needs at little or no extra cost over short life methods.

HAYS MFG. COMPANY Erie, Pa.

SINCE 1869

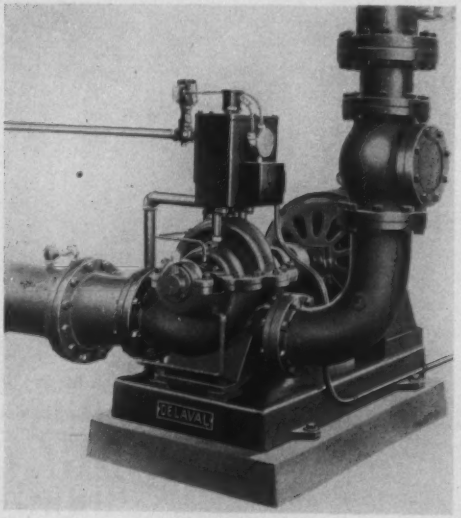
HAYS


STOP
TASTES and ODORS
in Raw Water Supplies with
INSURES PALATABLE
NUCHAR
DRINKING WATER
ACTIVATED CARBON
INDUSTRIAL CHEMICAL SALES DIVISION
OF WEST VIRGINIA PULP & PAPER CO.
230 Park Avenue, New York, N. Y.
1422 Widener Bldg. Philadelphia, Pa.
205 W. Wacker Drive Chicago, Ill.
617 Schofield Bldg. Cleveland, Ohio

DE LAVAL

CONTINUOUS AUTOMATIC PRIMING DEVICE

For Single Pumps



This small, compact apparatus is mounted as shown over the casing of a single De Laval centrifugal pump.
Continuously maintains suction lines and pump casing submerged at all times.

OPERATION WHOLLY AUTOMATIC

A small quantity of pressure water is required for initial starting and thereafter prime is maintained by the action of the pump itself.

INEXPENSIVE ECONOMICAL

This device can also be obtained with modifications for use where pressure water is not available.

Let us estimate on your priming problems.

TURBINE EQUIPMENT COMPANY OF NEW ENGLAND

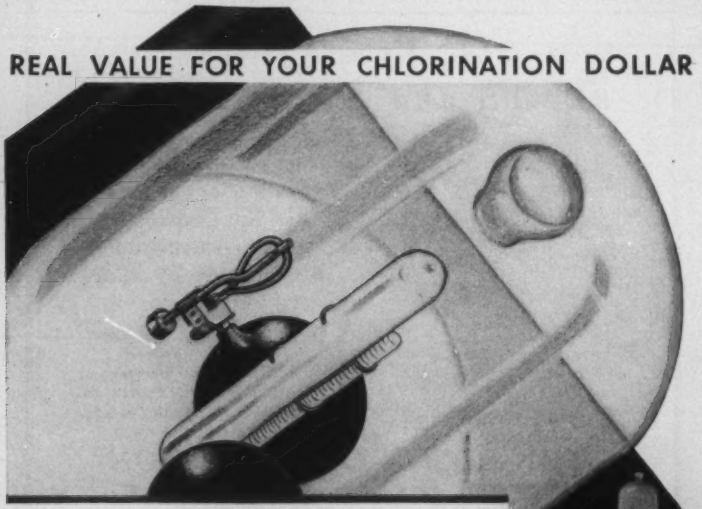
80 Federal Street Phone LIBerty 5993-5994 Boston, Mass.

New England Representative for

DE LAVAL STEAM TURBINE COMPANY

TRENTON, NEW JERSEY

REAL VALUE FOR YOUR CHLORINATION DOLLAR



GLASS HOUSES

are indispensable to chlorination

TROUBLE in a Visible Vacuum Chlorinator doesn't have a chance to develop into anything serious because the working parts are under the glass bell jar, always in plain sight.

But this is only one reason for Visible Vacuum Control. Visibility has an important corollary—Accessibility. When adjustments are needed—just drain the tray, lift the bell jar and the complete control mechanism is accessible for cleaning, repair or adjustment.

This important principle of combining Visibility and Accessibility, reinforced by standardized, high quality manufacturing and careful selection of the best materials has made the name "A W&T Visible Vacuum Chlorinator" synonymous with dependability, accuracy and low maintenance expense for over fifteen years.

When you are faced with the selection of equipment for the control of chlorination, visit a W&T Visible Vacuum installation. There you will learn why the Engineer, Superintendent and Public Health Official alike agree that Visible Vacuum Control is a real assurance for full value on your Chlorination dollar. Ask for technical publications 38, 157 and 158 describing W&T Visible Vacuum Chlorinators.

WALLACE & TIERNAN CO. INC.

Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK, N. J. Branches in Principal Cities

"The Only Safe Water is a Sterilized Water"

CHLORINATORS FOR WATER WORKS • SEWAGE PLANTS • SWIMMING POOLS
INDUSTRIAL PLANTS

Ad-55

EDSON
PUMPS and ACCESSORIES

Hand Pumps – Power Pumps
Truck or Trailer Mounted
Edson Special Suction Hose
Red Seal Diaphragms
Edson Bronze Hydrant Pump
Strainers, Adapters, etc.

Distributors for
Pollard Pipe Line Equipment
Redi-Prime Pumps
Electric Pipe Thawers
Standard Hydrant Protector
Universal Water Leak Detector

THE EDSON CORPORATION
49 D Street, Tel. SOUth Boston 3041 South Boston
New York: 142 Ashland Place, Brooklyn

Warren Foundry & Pipe Corp.
ALSO
Warren Pipe Co. of Mass., Inc.

SALES OFFICES
11 BROADWAY, NEW YORK
75 FEDERAL STREET, BOSTON, MASS.

Manufacturers of

CAST IRON PIPE

Flanged Pipe ***Flexible Joint Pipe***
Bell and Spigot Pipe
Special Castings ***Short Body B. & S. Specials***
Warren (WF) Spun Centrifugally Cast Iron Pipe

WORKS: PHILLIPSBURG, N. J. and EVERETT, MASS.

Large Stock Enables Us to Make Prompt Shipments

Few Products In Any Field Are So Clearly Recognized for Superiority of Service As

SPUN **BITUMASTIC** LINING

REG. U. S. PAT. OFF.

The Report of the Committee on PIPE LINE COEFFICIENTS of the New England Water Works Association definitely proves the absolute economic necessity of lining all water pipe.

BITUMASTIC SPUN LINING is assigned a higher value of the coefficient *C* than any other lining. This insures the highest initial flow. More important —this high flow will be maintained for many years.

BITUMASTIC ENAMEL is not affected by tuberculating waters. Actual inspection of pipe in service and carrying tuberculating waters shows BITUMASTIC unaffected. This is real proof.

No taste, color, or odor imparted to the water.

Write for further information.

Wailes Dove-Hermiston Corporation

17 Battery Place, New York, N. Y.

The "COREY" Hydrant

Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

Can be lengthened without shutting off water.

Will not flood if broken.

Positive Drip — cannot freeze.

Standpipe can be revolved quarter turns — Nozzles always in right direction.

Ask for our Catalog "G"

CHARLES L. BROWN,

New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY

TROY, N. Y.

DONALDSON IRON CO.

MANUFACTURERS

. . . OF . . .

CAST IRON PIPE

. . . AND . . .

Special Castings for Water and Gas
Also Flange Pipe and Fittings

EMMAUS, LEHIGH COUNTY, PA.

New York Office: E. A. NOONAN, 225 Broadway
New England Office: CHARLES F. GLAVIN, 35 Winslow Rd., Brookline, Mass.

WATER PROBLEM SOLVED BY NEEDHAM, MASS.

X. Henry Goodnough, Inc.
Engineers

● The town of Needham can well be proud of its new water pumping station, for as city officials state, "Our water troubles will be over for a good many years to come." Believed to be the first Municipal Diesel driven Turbine Pump installation in New England, this system is equipped with a Fairbanks-Morse single-cylinder Diesel which powers an F-M Turbine Pump to economically supply the best quality water from an underground reservoir.

Needham, as well as many other New England municipalities equipped by Fairbanks-Morse, is showing a substantial saving in operating costs. Get the facts on F-M power and pumping equipment by writing to Fairbanks, Morse & Co., 178 Atlantic Avenue, Boston, Mass.

FAIRBANKS-MORSE COMPANY

Power - Pumping - and - Weighing - Equipment

COPYRIGHT 1939 BY KEASBEY & MATTISON CO.

New...

"MAINS WITHOUT MAINTENANCE"

Get all the remarkable facts on "Century" Asbestos-Cement Pipe

One of the outstanding developments of recent years has been Asbestos-Cement pressure pipe . . . the answer to many of the most difficult problems formerly met in the distribution of water throughout a community. It has reduced pumping costs, cut maintenance, and ended tuberculation, corrosion and electrolysis.

Now, The Keasbey & Mattison Company, pioneers in asbestos products, announce "Century" Asbestos-Cement Pipe, made by a remarkable new process that produces a superior, tough, rugged pipe of high and uniform strength. Each length is subjected to a hydrostatic test of twice its normal working pressure.

It is light in weight for easy handling (8", Class 100 pipe, for example, weighs less than 13 lb. per linear foot), has a permanently smooth bore that cuts pumping costs (Williams and Hazen Constant of "C" 140), and never needs relining, or cleaning due to tuberculation or corrosion. It is of exceptionally long service life. "Century" Flexible Couplings provide permanently tight joints.

FREE — Complete, illustrated catalogue on "Century" Asbestos-Cement Pressure Pipe. Covers every phase of the subject, answering all your questions in detail. This book may help to save you thousands of dollars in pipe maintenance, in replacements, and in pumping cost.

KEASBEY & MATTISON COMPANY AMBLER, PENNA.

District Sales Offices in Principal Cities

MAIL THIS COUPON

KEASBEY & MATTISON CO., Ambler, Pa.

Send me, without obligation, free catalogue on "Century" Asbestos-Cement Pressure Pipe — "Mains Without Maintenance."

NAME _____

NAME OF PLANT _____

ADDRESS _____ JNEWWA-1

Haverhill, Mass.

Part of the Morris Centrifugal Pump installation at Haverhill, Mass. Metcalf & Eddy, Engineers.

one of 36 New England municipalities using MORRIS Centrifugal Pumps

Morris designs include standard centrifugal (single and multi-stage) mixed flow, propeller type, and straightflow pumps, each especially designed for certain conditions.

FLOOD control is a serious problem for many New England communities on large rivers like the Connecticut and the Merrimac. Haverhill is now assured of adequate protection because of its new pumping station, equipped with two 20-in. vertical mixed-flow 8300 g.p.m. Morris Pumps, one 16-in. vertical mixed-flow 4200 g.p.m. Morris Pump, and one 4-in. vertical non-clogging Morris Sump Pump. The high efficiencies which characterize all Morris Pumps assure low cost of pumping, whether motors or Diesel engines are used. If you are considering the purchase of centrifugal pumps for water supply, sewage disposal, storm water drainage, or flood protection, be sure to get a Morris quotation, based on 74 years of experience in building centrifugal pumps.

STARKWEATHER ENGINEERING COMPANY, Inc.
NEWTON, MASSACHUSETTS
New England Representative

MORRIS CENTRIFUGAL PUMPS

for every municipal service

Water Works Officials

Cultivate the goodwill of your customers

Use the

METER-MASTER

To settle high bill complaints

The METER-MASTER is the only portable rate recorder that gives a continuous record for 6 and 24 hour periods, or 24 and 72 hour periods, from either a single or a compound meter.

F. S. BRAINARD & CO.
246 Palm Street
Hartford, Connecticut

SHAKE WELL BEFORE USING!

doesn't apply to this Better Jointing Compound

Properly mixed at our plant, the solid ingot form cannot change composition en route to you. With *Tegul*-MINERALEAD there can be no settling of heavier particles to upset the value of the compound. ■ The 10 lb. ingot is also easy to handle, ship and store. Impervious to rain, snow and flood, it may be stored outdoors on the job. ■ *Tegul*-MINERALEAD means *quick-sealing*, permanently tight joints. Initial leakage heals so quickly that trenches can be back filled and premises cleared up almost immediately. ■ For further information, write The ATLAS MINERAL Products Company of Penna., Mertztown, Pennsylvania.

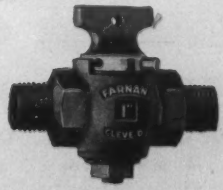
A Tegul PRODUCT

Tegul- MINERALEAD

Back of FARNAN

IS 86 YEARS OF EXPERIENCE SERVICE AND QUALITY

Our complete line consists of corporation and curb stops, couplings and fittings for copper, lead or iron SERVICE PIPE.



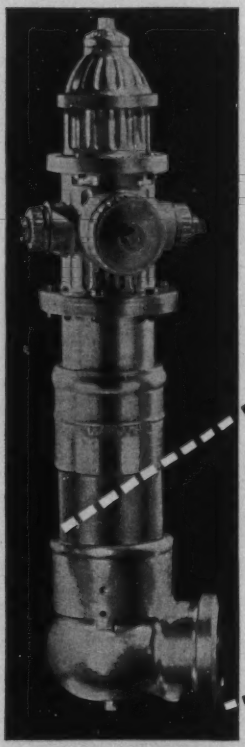
FARNAN BRASS WORKS CO.

Established 1852

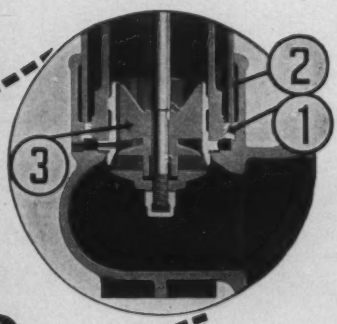
CLEVELAND **OHIO**

This underground construction should make you

Specify Mathews Hydrants



Even if Mathews Hydrants should cost more in the first place it would pay you to specify them for the savings in labor, maintenance, and repair. This is because the loose outer protection case of the Mathews Hydrant lets you unscrew and lift out its barrel which contains all operating parts. No digging is ever necessary. A smashed hydrant can be repaired instantly by inserting a new barrel. Periodic inspections and overhauls which include even the main and drain valve seats can be made above ground. Nozzle levels can be raised or lowered without excavating below the finished grade. Steamer nozzles can be added or removed by changing barrels. Specify this frost-proof hydrant that you can "change like a tire." Your city will pay less for its fire protection.



1. The entire barrel unscrews here for removal.
2. The protection case is loose, free to move with frost.
3. A positive and automatic drain valve which can't fail.

MATHEWS HYDRANTS

Made by R. D. WOOD COMPANY

Manufacturers of Sand Spun Pipe (centrifugally cast in sand molds) and R. D. Wood heavy-duty gate valves for water works

400 CHESTNUT STREET, PHILADELPHIA, PA.

CLASSIFIED DIRECTORY OF ADVERTISEMENTS

ACTIVATED CARBON.
Industrial Chemical Sales Division—West Virginia Pulp and Paper Co. xix

AIR CONDITIONING EQUIPMENT.
Worthington Pump and Machinery Corp. vii

AIR COMPRESSORS.
Worthington Pump and Machinery Corp. vii

ASBESTOS CEMENT PIPE.
Johns-Manville xi
Keasbey & Mattison Co. xxv

BRASS GOODS.
(See also Pipe, Brass.)
Caldwell, George A., Co. xxxv
Cement Lined Pipe Co. viii
Farnan Brass Works Co. xxvii
Hays Mfg. Co. xviii
Mueller Co. xxxiii
Pierce-Perry Co. viii
Red Hed Mfg. Co. xxxiv
Smith Mfg. Co., The A. P. xvii

CALKING MACHINERY AND TOOLS.
Mueller Co. xxxiii
Smith Mfg. Co., The A. P. xvii

CAST IRON PIPE. (See Pipe, Cast Iron.)

CEMENT LINED PIPE. (See Pipe, Cement Lined)

CHECK VALVES.
Darling Valve & Mfg. Co. ix
Mueller Co. xxxiii

CHEMICAL FEED APPARATUS.
Wallace and Tiernan Co., Inc. xxi

CHLORINATORS.
Wallace & Tiernan Co., Inc. xxi

CLAMPS, RIVER.
Dresser, S. R., Mfg. Co. Following front cove

CLAMPS, SERVICE.
Mueller Co. xxxiii

CLEANING WATER MAINS.
National Water Main Cleaning Co. viii

COCKS, CURB AND CORPORATION.
Caldwell, George A., Co. xxxv
Farnan Brass Works Co. xxvii
Hays Mfg. Co. xviii
Mueller Co. xxxiii
Pierce-Perry Co. viii
Red Hed Mfg. Co. xxxiv
Smith Mfg. Co., The A. P. xvii

CONCRETE PIPE. (See Pipe, Concrete.)

CONDENSERS.
Worthington Pump and Machinery Corp. vii

CONTRACTORS' EQUIPMENT
Morris Machine Works xxvi
Worthington Pump and Machinery Corp. vii

CONSTRUCTION EQUIPMENT.
Edson Corp., The xxii

CONSTRUCTION AIR TOOLS
Worthington Pump and Machinery Corp. vii

CONTRACTORS.
Layne-Bowler New England Co. iii
National Water Main Cleaning Co. viii
Reppucci, C. & Sons, Inc. iii

COUPLINGS, FLEXIBLE PIPE.
Dresser, S. R., Mfg. Co. Following front cover

COUPLINGS, REPAIR.
Caldwell, George A., Co. xxxv

CURB BOXES.
Bingham and Taylor iv
Caldwell, George A., Co. xxxv
Farnan Brass Works Co. xxvii
Hays Mfg. Co. xviii
Mueller Co. xxxiii

CURB AND VALVE BOX FINDERS.
Caldwell, George A., Co. xxxv

DIAPHRAGMS, PUMP.
Edson Corp., The xxii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

ENGINEERS. Page

Bailey, Howard E. iii
Barbour, Frank A. ii
Barrows, H. K. ii
Crosby, Irving B. iii
Ellsworth, Samuel M. ii
Fay, Spofford & Thorndike ii
Goodnough, Inc., X. Henry ii
Metcalf & Eddy ii
Newsom, Reeves ii
Pirnie, Malcolm ii
Pitometer Co ii
Weston & Sampson iii
Whitman & Howard iii

ENGINES. (See Pumps and Pumping Engines.)

EQUIPMENT. (See Contractors' Equipment.)

ERECTORS, WATER WORKS AND POWER MACHINERY
Turbine Equipment Co. xx

FEED WATER HEATERS.
Ross Valve Mfg. Co. viii
Worthington Pump and Machinery Corp. vii

FILTER RATE CONTROLLERS AND GAGES. (See Rate Controllers)

FILTERS AND WATER SOFTENING PLANTS.
Ross Valve Mfg. Co. viii

FILTRATION PLANT EQUIPMENT.
Morris Machine Works xxvi
Ross Valve Mfg. Co. viii
Wallace & Tiernan Co., Inc. xxi

FLEXIBLE JOINTS.
U. S. Pipe and Foundry Co. ..... Facing back cover

FLAP VALVES.
Mueller Co. xxxiii

FURNACES, ETC.
Atlas Mineral Products Co. xxvii
Leadite Co., The ..... Back cover
Mueller Co. xxxiii
Smith Mfg. Co., The A. P. xvii

GATE VALVES. (See Valves.)

GUNITE.
National Gunite Contracting Co. iii

HOSE, SUCTION AND CONDUCTION.
Edson Corp., The xxii

HYDRANT PROTECTORS.
Edson Corp., The xxii

HYDRANTS, FIRE.
Darling Valve & Mfg. Co. ix
Eddy Valve Co. xv
Kennedy Valve Mfg. Co. xiv
Ludlow Valve Mfg. Co. xvi
Mueller Co. xxxiii
Rensselaer Valve Co. xxiii
Ross Valve Mfg. Co. v
Smith Mfg. Co., The A. P. xvii
Wood, R. D., Co. xxviii

HYDRANT PUMPS.
Edson Corp., The xxii

INSTRUMENTS. (See Water Works Instruments.)

LEAD.
National-Boston Lead Co. xvi

LEAD PIPE. (See Pipe, Lead.)

LEAD WOOL.
National-Boston Lead Co. xvi

LEAK FINDERS.
Pitometer Co. ii
Edson Corp., The xxii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

METERS, WATER AND OIL. Page
Hersey Mfg. Co. ... v
National Meter Co. ... xii
Neptune Meter Co. ... vi
Pitometer Co. ... ii
Pittsburgh Equitable Meter Co. ... Following front cover
Worthington Pump and Machinery Corp. ... vii

METER COUPLINGS.
Ford Meter Box Co. ... xvii

METERS (VENTURI TYPE).
Mueller Co. ... xxxiii
National Meter Co. ... xii

METER BOXES.
Bingham and Taylor ... iv
Ford Meter Box Co. ... xvii

METER MASTER.
Brainard, F. S. & Co. ... xxvii

METER TESTERS.
Ford Meter Box Co. ... xvii
Mueller Co. ... xxxiii

OIL ENGINES, DIESEL.
Fairbanks-Morse Co. ... xxiv
Worthington Pump and Machinery Corp. ... vii

PAINTING.
Tredennick, J. H., Inc. ... Preceding index of advertisers

PIPE, BRASS.
Caldwell, George A., Co. ... xxxv
Pierce-Perry Co. ... viii

PIPE, CAST IRON (AND FITTINGS).
Donaldson Iron Co. ... xxiv
U. S. Cast Iron Pipe and Foundry Co. ... Facing back cover
Warren Foundry and Pipe Corp. ... xxii
Wood, R. D., Co. ... xxviii

PIPE, CEMENT LINED.
Cement Lined Pipe Co. ... viii

PIPE, CENTURY
Keasbey & Mattison Co. ... xxv

PIPE, CONCRETE.
Lock Joint Pipe Co. ... Facing front cover

PIPE CUTTING MACHINES.
Smith Mfg. Co., The A. P. ... xvii

PIPE JOINTING MATERIAL.
Atlas Mineral Products Co. ... xxvii
Hydraulic Development Co. ... x
Leadite Co., The ... Back cover

PIPE, LEAD.
National-Boston Lead Co. ... xvi

PIPE LINING.
Wailes Dove-Hermiston ... xxiii

PIPE, TRANSITE.
Johns-Manville ... xi

PIPE, WROUGHT IRON AND STEEL.
Pierce-Perry Co. ... viii

PLUG VALVES.
Mueller Co. ... xxxiii

PITOMETERS.
Pitometer Co. ... ii

PORTABLE AIR COMPRESSORS. (See Air Compressors)

POWER WIRE BRUSH, INC.
Tredennick, J. H., Inc. ... Preceding index of advertisers

PRESSURE REGULATORS.
Caldwell, George A., Co. ... xxxv
Mueller Co. ... xxxiii
Ross Valve Mfg. Co. ... viii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

PROVERS, WATER. Page
Pittsburgh Equitable Meter Co. ..... Following front cover

PUMPS AND PUMPING ENGINES.
Edson Corp., The xxii
Fairbanks-Morse & Co. xxiv
Morris Machine Works xxvi
Ross Valve Mfg. Co. viii
Turbine Equipment Co. xx
Wood, R. D., Co. xxviii
Worthington Pump and Machinery Corp. vii

RATE CONTROLLERS.

SHEAR GATES.
Mueller Co. xxxiii

SLEEVES, PIPE LINE PEPAIR.
Dresser, S. R., Mfg. Co. ..... Following front cover

SLEEVES, RIVER.
Dresser, S. R., Mfg. Co. ..... Following front cover

SLEEVES AND VALVES, TAPPING.
Ludlow Valve Mfg. Co. xvii
Mueller Co. xxxiii
Rensselaer Valve Co. xxiii
Smith Mfg. Co., The A. P. xvii

SLUICE GATES.
Mueller Co. xxxiii

STANDPIPES.
Tredennick, J. H., Inc. ..... Preceding index of advertisers

SUPPLIES AND TOOLS.
Caldwell, George A., Co. xxxv
Farnan Brass Works Co. xxvii
Hays Mfg. Co. xviii
Leadite Co., The ..... Back cover
Pierce-Perry Co. viii
Smith Mfg. Co., The A. P. xvii

TAPPING MACHINES.
Hays Mfg. Co. xviii
Mueller Co. xxxiii
Red Hed Mfg. Co. xxxiv
Smith Mfg. Co., The A. P. xvii

TAPPING SLEEVES. (See Sleeves and Valves, Tapping)

VALVE BOXES.
Bingham and Taylor iv
Caldwell, George A., Co. xxxv
Ford Meter Box Co. xvii
Mueller Co. xxxiii
Rensselaer Valve Co. xxiii
Wood, R. D., Co. xxviii

VALVE INSERTING MACHINES.
Smith Mfg. Co., The A. P. xvii

VALVES, GATE.
Darling Valve & Mfg. Co. ix
Eddy Valve Co. xv
Kennedy Valve Mfg. Co. xiv
Mueller Co. xxxiii
Rensselaer Valve Co. xxiii
Ross Valve Mfg. Co. viii
Smith Mfg. Co., The A. P. xvii
Wood, R. D., Co. xxviii

VALVES, REGULATING.
Mueller Co. xxxiii
Ross Valve Mfg. Co. viii

WATER WASTE DETECTION.
Pitometer Co. ii

WATER WORKS INSTRUMENTS.
Caldwell, George A., Co. xxxv

WATER WORKS JOURNALS.
Journal of the New England Water Works Association ii

WELL CONNECTIONS.
Red Hed Mfg. Co. xxxiv

WROUGHT IRON PIPE. (See Pipe, Wrought Iron and Steel)

USED TO ROUGH STUFF

WATER TAPPING MACHINE "B."

For tapping water mains and inserting corporation stops ¾" to 1" inclusive under pressure. This machine will also make taps only from ¾" to 2½" inclusive in dry mains.

DRILLING MACHINE "E-4."

For drilling dry or pressure mains through stops, valves or fittings with a capacity of 7-16" to 1" inclusive.

If you are wrestling with Tapping or Drilling problems, you had better take a look at your red Mueller Catalog "H" and investigate the complete line of Mueller Tapping and Drilling Machines.

These machines do many jobs with ease and dispatch. They will drill, tap and insert corporation stops in mains under pressure without shutting down the line or interrupting service. They may be adapted to other purposes such as inserting pipe plugs or will do straight drilling or tapping operations in dry pipe. The small drilling machines will drill through service clamps and corporation stops where the main is too small, weak or thin to permit tapping and the large drilling machines will drill through tapping sleeves and valves for making lateral or branch connections to main under pressure.

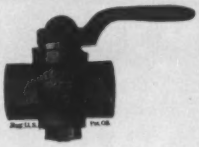
Mueller Tapping and Drilling Machines are a necessity for economical installation and maintenance work on water distribution systems. Perhaps you already have a Mueller Machine that has given you excellent service but is now getting a little old. If that is the case, we can recondition it or make you a liberal allowance on a trade-in for a new, up-to-date machine. Write us for the facts today.

●

MUELLER CO.

DECATUR, ILLINOIS

"MUELLER"—THE ACCEPTED STANDARD.



R
HED
D

THE RED HEDS ON YOUR STOPS AND CORPORATIONS ARE INSURANCE AGAINST HIGH MAINTENANCE COSTS.

RED HED MFG. CO.

Makers of

RED HED BRASS GOODS FOR WATERWORKS

368 Congress Street **Boston, Mass.**

CURB - ROADWAY & VALVE BOX

SERVICE for 1939

150 Styles, Sizes and Lengths Always in Stock

90% of Orders are Shipped on Day of Receipt

This Service, the Quality and the Net Price combines to your profit and our ever-growing Box business.

A-34 No. 1

Stocked in
4 to 6 ft.
lengths

A-38

A-44

Stocked in
4 to 7 ft.
lengths

No order too large nor none too small to receive our prompt attention and appreciation.

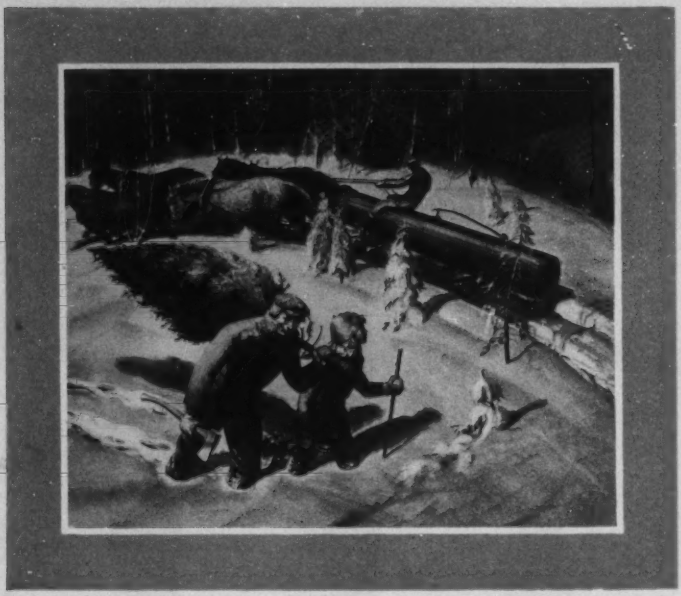
P. S. Adequate stocks of extension pieces, all types for Curb-Roadway and Valve Boxes available to you.

GEORGE A. CALDWELL COMPANY

Everything For Water Service Work from Main to Meter

Phone BLUe Hills 2791

BOSTON **Mattapan Square** **MASSACHUSETTS**



Lithographed on stone by James E. Allen for U. S. Pipe & Foundry Co.
Copyright 1939, U. S. Pipe & Foundry Co.

Beginning the eighth year of cumulative evidence that Superde Lavaud Cast Iron Pipe, produced by a revolutionary method whereby gray iron is *centrifugally cast in a metal mold without chill*, has extraordinary toughness, ductility and resistance to impact.

United States Pipe & Foundry Co., Burlington, N. J.

U.S.
cast iron
PIPE

Plants and Sales Offices throughout the United States

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness.

All members of the Association receive the JOURNAL for two dollars per annum which sum is included in their annual dues; to all others the subscription is four dollars per annum.

TO ADVERTISERS

THE attention of parties dealing in goods used by Water Departments is called the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION as an advertising medium.

Its subscribers include the principal WATER WORKS ENGINEERS and CONTRACTORS in the United States. The paid circulation is **1000** COPIES.

Being filled with original matter of the greatest interest to Water Works officials it is PRESERVED and constantly REFERRED TO BY THEM, and advertisers are thus more certain to REACH BUYERS than by any other means.

The JOURNAL is not published as a means of revenue, advertisements being inserted solely to help meet the large expense of publication.

ADVERTISING RATES

One page, one year, four insertions	Eighty Dollars
One-half page, one year, four insertions	Fifty-six Dollars
One-fourth page, one year, four insertions	Thirty-six Dollars
One-twelfth page (card), one year, four insertions	Twelve Dollars
One page, single insertion	Forty Dollars
One-half page, single insertion	Thirty Dollars
One-fourth page, single insertion	Twenty Dollars

Size of page, 4½ x 7½ net.

A sample copy will be sent on application.

For further information, address the Advertising Agent,

(Miss) MARCELLA SACHS,
613 STATLER BUILDING,
BOSTON, MASS.

LEADITE

—offers these advantages for Bell and Spigot Water Pipe Line Construction.

Effects a Saving in Cost of Material.

Saves the Expense of Caulking.

Reduces Cost of digging bell holes.

Is Light in weight and Easy to handle.

Speeds up Completion of the job, thereby saving large sums in "Interest Charges"—and making the water line a "Revenue Producer" in quicker time.

Leadite has been used on thousands of miles of Bell and Spigot Pipe with great success.

The pioneer self-caulking material for c.i. pipe.

Tested and used for over 35 years.

Saves at least 75%.

THE LEADITE COMPANY

Girard Trust Company Bldg. Philadelphia, Penna.